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Aggregate Resources Inventory of

Burleigh and Anstruther Township, Chandos Township and Methuen Geographic Township

Peterborough County

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Abstract

This report includes both an inventory and an evaluation of sand and gravel, as well as bedrock resources, in Burleigh and Anstruther Township, Chandos Township and Methuen geographic township. The report is based on previous studies in the area and a detailed field assessment undertaken in the spring of 1988. The investigation was conducted to delineate and determine the quality and quantity of aggregate within the area to help ensure sufficient aggregate resources are available for future uses.

Five ice-contact and outwash deposits, which contain locally significant amounts of sand and gravel, have been selected as resource areas of primary significance. These Selected Sand and Gravel Resource Areas occupy approximately 470 acres (190 ha), of which an estimated 365 acres (148 ha) are currently available for extraction and contain aggregate resources of approximately 7.8 million tons (7.1 million tonnes). In addition, several outwash deposits and an ice-contact deposit in the study area have been classified as aggregate resources of secondary significance.

Sand and gravel resources are somewhat limited in the report area. Scattered sand deposits are located in Burleigh, Anstruther and Methuen geographic townships. Chandos geographic township has extensive sand deposits, but these sources are generally limited to supplying low specification aggregate. Gravel deposits are very scarce and occur only in Chandos and Methuen geographic townships. The use of selective extraction and/or sand control methods is generally necessary to obtain crushable gravel from these deposits.

The lack of naturally occurring high specification aggregate has resulted in the importation of crushed stone into the area. However, there are some local sources of potentially good quality material. The townships are underlain predominantly by Precambrian rocks. Marble has been quarried in two locations in the area, and it may be suitable for use as crushed stone. In Methuen geographic township, highly weathered gneisses are being extracted for use on local cottage roads. There are also Paleozoic outliers in southern Burleigh and Methuen geographic townships, in which two quarries have been opened. The limestones of the Gull River and Bobcaygeon formations have been selected as Bedrock Resource Areas 1 and 2. Crushed stone produced from these formations is potentially suitable for use in granular base course and subbase course products. Although the crushed limestone may meet specifications, some of it may not be accepted by the Ontario Ministry of Transportation for use in concrete aggregate because of the possible presence of alkali-reactive beds. The Selected Bedrock Resource Areas contain possible resources of approximately 630 million tons (570 million tonnes).

Selected Resource Areas are not intended to be permanent, single land use units. They represent areas in which a major resource is known to exist and may be reserved wholly or partially for extractive development and/or resource protection.

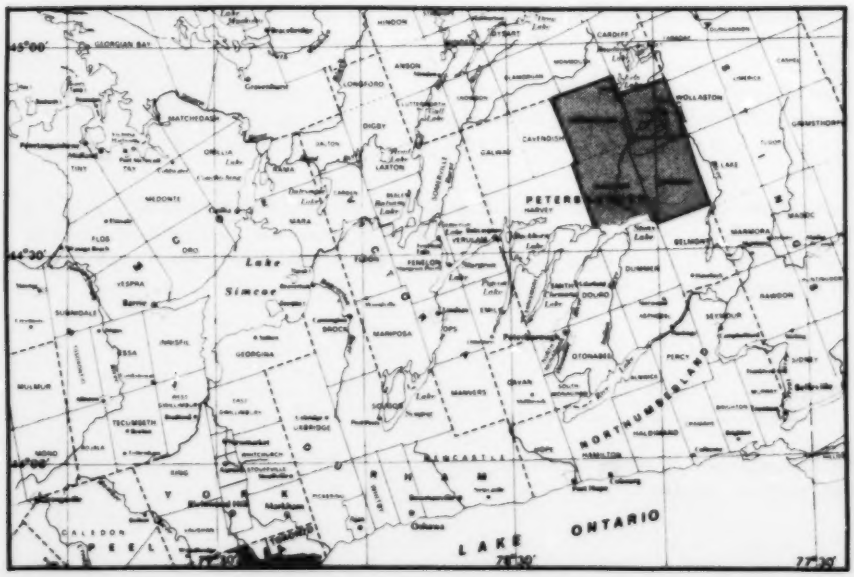

Figure 1. Key map showing the location of Burleigh and Anstruther Township, Chandos Township and Methuen Geographic Township, scale 1:1 800 000.

Résumé

Ce rapport comprend à la fois un inventaire et une estimation des ressources en sable et gravier ainsi que des ressources du substratum rocheux dans le canton de Burleigh et Anstruther, le canton de Chandos et le canton géographique de Methuen. Il est basé sur des études précédentes du secteur ainsi qu'une évaluation détaillée faite sur le terrain au cours du printemps 1988. Ces études ont été entreprises dans le but de délimiter et de déterminer la qualité et la quantité d'agrégat présent dans le secteur étudié afin de s'assurer que la région possède des ressources d'agrégat suffisantes pour des utilisations futures.

Cinq dépôts de contact glaciaire et d'épandage fluvio-glaciaire, contenant par endroits des quantités importantes de sable et de gravier, ont été choisis comme zones de ressources de première importance. Ces zones occupent approximativement 470 acres (190 ha) dont 365 acres (148 ha) sont actuellement disponibles pour l'exploitation. Ces cinq dépôts contiennent approximativement 7,8 millions de tonnes (7,1 millions de tonnes métriques) d'agrégat. Il faut également signaler que, dans le secteur étudié, plusieurs dépôts d'épandage fluvio-glaciaire et un dépôt de contact glaciaire ont été classifiés comme ressources d'agrégat d'importance secondaire.

Dans le secteur décrit dans le rapport, les ressources en sable et gravier sont restreintes. Des dépôts de sable sont dispersés dans les cantons géographiques de Burleigh, Anstruther et Methuen. Le canton de Chandos renferme des dépôts de sable importants mais, d'une manière générale, ces sources ne peuvent fournir qu'un agrégat de qualité moindre. Les dépôts de gravier sont peu abondants et se situent seulement dans les cantons géographiques de Chandos et de Methuen. L'usage de méthodes d'extraction sélective et/ou de contrôle du sable s'avère généralement nécessaire afin d'obtenir du gravier concassable à partir de ces dépôts.

Le substratum de ces cantons est formé en grande partie de roches précambriennes. Du marbre, pouvant être utilisé comme pierre concassée, a été extrait en deux endroits dans le secteur. Dans le canton géographique de Methuen, des gneiss fortement altérés sont extraits pour être utilisés comme revêtement des routes d'accès aux chalets. On trouve aussi des buttes-témoin de roches paléozoïques dans la partie sud des cantons géographiques de Burleigh et Methuen où deux carrières ont été ouvertes. Les calcaires des formations de Gull River et de Bobcaygeon ont été sélectionnés comme secteurs 1 et 2 de ressources du substratum. La pierre concassée produite à partir de ces formations peut convenir comme produit pour la base et la sous-base granuleuse des routes. Bien que le calcaire concassé puisse répondre aux spécifications, une partie risque de ne pas être acceptée par le ministère ontarien des Transports en tant qu'agrégat pour le béton à cause de la présence éventuelle de lits alcalins-réactifs. Les zones sélectionnées pour les ressources en matériaux de leur substratum contiennent environ 630 millions de tonnes (570 millions de tonnes métriques) en ressources possibles.

Les zones de ressources sélectionnées ne sont pas destinées à un usage unique et permanent. Elles représentent des secteurs dans lesquels une ressource importante est reconnue et peut être réservée entièrement ou partiellement pour l'exploitation et/ou comme réserve de ressources.

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Aggregate Resources Inventory of Burleigh and Anstruther Township, Chandos Township and Methuen Geographic Township

Peterborough County

By Staff[1] of the Engineering and Terrain Geology Section

[1] Project Supervisor: I. Szoke; field work and report by C. J. Dawson; compilation and drafting by Staff of the Aggregate Assessment Office. Assistance with review provided by the Resident Geologist of the Southeastern District of the Ministry of Northern Development and Mines. The Mineral Resources Staff of Bancroft District Office of the Ministry of Natural Resources assisted in the collection of data, field checking and review of this report.

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Introduction

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1987, the total tonnage of mineral aggregates extracted was 156 million tons (142 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Northern Development and Mines 1989).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential of bedrock-derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

Part I — Inventory Methods

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (*see* References) as well as field examination of potential resource areas. Field methods include the examination of natural and man-made exposures of granular material. Most observations are made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites include estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations are also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, subsurface materials may be assessed by hand augering and test pitting, supplemented by test hole drilling, and geophysical surveys using hammer seismic equipment. The symbols for and locations of sample sites, test hole sites, and geophysical traverse lines are noted on Map 1.

Deposits with potential for further extractive development or those where existing data are scarce, are studied in greater detail. Representative layers in these deposits are sampled in 25- to 100-pound (11 to 45 kg) units from existing pit faces or from test pits. The samples are analysed for grain size distribution, and in some cases absorption, Los Angeles abrasion, and Magnesium Sulphate soundness tests and petrographic analyses are carried out. Analyses are performed either in the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation, or in the Geoscience Laboratory, Ontario Geological Survey.

The field data are supplemented by pit information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation. Data contained in these files include field estimates of the depth, composition, and "workability" of deposits, as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The cooperation of the above-named group in the compilation of inventory data is gratefully acknowledged.

Aerial photographs at various scales are used to determine the continuity of deposits, especially in areas where information is limited. Water well records, held by the Ontario Ministry of the Environment, are used in some areas to corroborate deposit thickness estimates or to indicate the presence of buried granular material. These records are used in conjunction with other evidence.

Topographic maps of the National Topographic System, at a scale of 1:50 000, are used as a compilation base for the field and office data. The information is then transferred to a base map, also at a scale of 1:50 000. These base maps are prepared by the Surveys, Mapping and Remote Sensing Branch, Ontario Ministry of Natural Resources with information taken from maps of the National Topographic System by permission of Energy, Mines and Resources Canada, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been established, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as test holes and water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot (0.3 m) thick layer of sand and gravel, one acre (0.4 ha) in extent, assuming an average density of 110 pounds per cubic foot (1766 kg/m^3).

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e., original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of acres unavailable because of the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted. The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage (Column 7) presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however, the aggregate potential of these deposits is discussed in the report.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps, and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated quarriable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of 60 feet (18 m) is used for thickness. Volume estimates are then multiplied by the density factor [the estimated weight in tons of a one-foot (0.3 m) thick section of rock, or ... acre (0.4 ha) in extent].

Resources of dolostone are calculated using a density factor of 165 pounds per cubic foot (2649 kg/m^3) or 3600 tons per acre (8070 tonnes per hectare). Sandstone resources are calculated using a density estimate of 146 pounds per cubic foot (2344 kg/m^3) and shale resources are calculated with a factor of 150 pounds per cubic foot (2408 kg/m^3).

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel deposits are termed possible resources (*see* Glossary, Appendix B) in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p.7) and with the Association of Professional Engineers of Ontario (1976).

Part II — Data Presentation and Interpretation

Three maps, each portraying a different aspect of the aggregate resources in the area, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources", shows the distribution of Paleozoic bedrock formations, the areas of undifferentiated Precambrian bedrock, the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

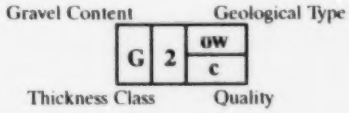
Map 1 is derived from existing surficial geology maps of the area or from aerial photograph interpretation in areas where surficial mapping is incomplete. The map shows the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

On the map, gravel deposits are indicated by dark brown shading while sand deposits are shaded light brown. The present level of extractive activity is also indicated. Pits are identified by a number which refers to a description in Table 2. Each description notes the location, estimated face height and percentage gravel. Similarly, test hole locations appear on Map 1 as a point symbol and are described in Table 7. Geophysics lines are shown on Map 1 by a line symbol and are interpreted in Table 8.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for every deposit shown on Map 1. These components are illustrated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35% gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35% of the whole deposit. "G" indicates that the deposit contains more than 35% gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the deposit types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution of material sampled during field study. These symbols are derived from the information plotted on the aggregate grading curves found in the report. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically in the Texture Symbol by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30% gravel, 60% sand, and 10% silt and clay:

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary, secondary and tertiary. Each area of primary significance is given a deposit number and all such deposits are shown by dark red shading on Map 2.

Selected Sand and Gravel Resource Areas of primary significance are not intended to be permanent, single land use units. They represent areas in which a major resource is known to exist and may be reserved wholly or partially for extractive development and/or resource protection.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by light red shading on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resources in the report area, they may contain large quantities of sand and gravel and should be considered as part of the aggregate supply of the area.

Areas of tertiary significance are outlined on the map by a solid line but have no shading. They are not considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the report area is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

Deposit Size

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1 [greater than 20 feet (6 m) thick], and containing more than 35% gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

Aggregate Quality

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the deposit symbols on Map 1. They are: gravel content (G or S), fines (C), oversize (O) and lithology (L).

Three of the quality indicators deal with grain size distribution. The gravel content (G or S) indicates the suitability of aggregate for various uses. Deposits containing at least 35% gravel in addition to a minimum of 20% material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (high silt and clay content) may severely limit the potential use of a deposit. Fines content in excess of 10% may impede drainage in road subbase aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20% oversize material [greater than 4 inches (10 cm) in diameter] may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

Another indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock types determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high quality uses such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol shows either "C", "O", or "L" or any combination of these indicators, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt is made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Quality data may also appear in Table 9, where the results of aggregate quality tests are listed by test type and sample location. The types of tests conducted and the test specifications are explained in Appendixes B and E, respectively.

Analyses of unprocessed samples obtained from test holes, pits or sample sites are plotted on grain size distribution graphs. On the graphs are the Ontario Ministry of Transportation's gradation specification envelopes for aggregate products: Granular Base Course A, B and C, Hot-Laid Asphaltic Sand Nos. 1,2,3,4, and 8, and concrete sand. By plotting the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product. These graphs, called Aggregate Grading Curves, follow the tables in the report.

Location and Setting

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the pertinent District Office of the Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain roughly at the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalities with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, drift thickness and bedrock topography maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources) and from geotechnical test hole data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the Paleozoic bedrock units are shown by a dashed line. The areas of undifferentiated Precambrian bedrock are labelled as such on Map 3. Isolated Paleozoic outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, areas of 25 to 50 feet (8 to 15 m) of drift and areas of greater than 50 feet (15 m) of drift. The extent of these areas of drift are shown by four shades of blue. The darkest shade indicates where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas constitute potential resource areas because of their easy access. The medium to dark shade indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these zones also represent potential resource areas. The medium to light shade indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. The lightest shade of blue indicates areas overlain by greater than 50 feet (15 m) of drift, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive deposits). Outside of these delineated areas are areas of undifferentiated Precambrian bedrock, with varying thicknesses of drift cover.

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the report area. Quarries are identified by a number which refers to the descriptions in Table 5. Each description notes the location and an estimate of face height. Two additional symbols may appear on the map. An open dot indicates the location of a selected water well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot. Similarly, test hole locations appear as a point symbol

with the depth to bedrock shown in feet beside it. The test holes may be further described in Table 7.

SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select Paleozoic bedrock areas most favourable for extractive development. The areas of Precambrian bedrock are not evaluated in this report.

The evaluation of Paleozoic bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation. The main characteristics and uses of the bedrock units found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations. Since vertical and lateral variations in Paleozoic bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource are usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

The Precambrian Shield rocks are generally more complex and variable than the Paleozoic rocks of Ontario. They often show wide variations in mineralogy, texture (grain size), joint patterns and degree of weathering, even with specific rock types and over relatively short distances. As these factors are considered important in determining the suitablity of the bedrock for the use as aggregate, the aggregate potential may also vary considerably from location to location.

Careful selection is especially important if the bedrock is to be used as concrete aggregate. Deleterious chemical reactions may develop in the concrete which can lead to its eventual deterioration. Fortunately, these chemical reactions should not influence the use of bedrock-derived aggregate for such uses as roadbase material. However, highly weathered, very porous and friable rock should be avoided for all uses.

For these reasons, no specific Precambrian bedrock resources have been selected for resource protection. A summary of the bedrock resources on a regional level is included in the Bedrock Geology section.

SELECTED RESOURCE AREAS

Selection of Bedrock Resource Areas has been restricted to a single level of significance. Three factors support this approach. First, quality and quantity variations are gradual. Second, the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material, and third, since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The Selected Areas, if present, are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units. They represent areas in which a major bedrock resource is known to exist and may be reserved wholly or partially for extractive development and/or resource protection.

Part III—Assessment of Aggregate Resources in Burleigh and Anstruther Township, Chandos Township and Methuen Geographic Township

LOCATION AND POPULATION

The report area includes the four geographic townships of Burleigh, Anstruther, Chandos and Methuen. These townships are located in northeastern Peterborough County, southern Ontario. The townships occupy an area of approximately 270,000 acres (110 000 ha). These townships are shown on the Bannockburn (31 C/12), Burleigh Falls (31 D/9), Coe Hill (31 C/13) and Gooderham (31 D/16) map sheets of the National Topographic System, at a scale of 1:50 000.

The four geographic townships in the report area have been incorporated into municipal townships. Chandos geographic township forms a municipal township of the same name. Burleigh and Anstruther geographic townships form a single municipal township called Burleigh and Anstruther Township. Methuen geographic township has been incorporated with Belmont geographic township (which is located south of the project area) to form Belmont and Methuen Township.

The permanent population of the townships of Burleigh, Anstruther and Chandos was 1664 in 1985, an increase of more than 3% from 1980. In Belmont and Methuen Township the permanent population was 2282 in 1985, an increase of almost 3% from 1980 (Ontario Ministry of Intergovernmental Affairs 1981; Ontario Ministry of Municipal Affairs 1988). Only a small portion of the permanent population of Belmont and Methuen Township lives in Methuen geographic township.

The largest community in the report area is Apsley with a population of 450 (Ontario Ministry of Transportation 1988). Several smaller communities such as Nephton, Woodview, Jack Lake, Glen Alda and Mount Julian are also located in the report area. Although tourism is the dominant economic activity in the area, a limited amount of mixed farming occurs, and an open pit nepheline-syenite mine operates near Nephton in Methuen geographic township.

The area has attracted a lot of cottagers, and the major lakes in the area such as Stoney, Jack, Kasshabog, Anstruther and Chandos lakes, are lined with their dwellings. Hunting camps are also numerous in the less inhabited parts of the townships. Petroglyphs Provincial Park is a tourist attraction in southern Burleigh geographic township. Also, an area in southwestern Anstruther geographic township has been classed by the Ministry of Natural Resources as a nature reserve, the Kawartha Highlands Provincial Park.

King's Highway 28 links the report area to population centres in the southwest and northeast. Other transportation routes include Secondary highways 504, 620 and 620A, and regional and township roads. A number of forest and cottage access roads cover a large part of the report area, but there are still areas which are inaccessible.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

Approximately 23 000 to 10 000 years ago, during the late Wisconsinan Substage of the Pleistocene Epoch (informally known as the "Great Ice Age"), lobes or submasses of the Laurentide ice sheet advanced out of the basins of the Great Lakes and joined together to cover southern Ontario. The lateral extent of the ice lobes and the positions of their margins underwent numerous fluctuations until approximately 13 000 years ago, at which time the ice receded to the north of the study area. The physiography and surficial geology of Burleigh, Anstruther, Chandos and Methuen geographic townships are largely the result of the glacial activity and the nature and form of the bedrock.

In the report area the glacial and postglacial deposits and the underlying bedrock combine to form two physiographic regions (Chapman and Putnam 1984). The northern part of the report area is part of the Algonquin Highlands - a region where bedrock knobs and ridges are interspersed with areas containing various thicknesses of till or other glacial deposits. The Georgian Bay Fringe physiographic region includes the southern part of the area, and is characterized by very shallow soil and exposed bedrock.

The bedrock of the report area is predominantly Precambrian in age, with isolated areas of Paleozoic-age rocks in the south. The bedrock is commonly covered by a thin mantle of till laid down by the glacier. There are also areas where thicker till sequences have been deposited. Ice flow in the eastern part of Chandos geographic township was generally in a southerly direction (Finamore and Courtney 1982). Detailed information concerning ice flow direction over the remainder of the report area is not available. The till deposited by the ice is generally not acceptable for use as aggregate because it has a high fines content and contains abundant oversize boulders, however, in aggregate-poor areas it has been used for cottage road construction and fill.

Several deposits of ice-contact stratified drift were deposited in close proximity to the ice front as it melted northward. These widely scattered mound-shaped features were deposited by a variety of depositional processes and contain aggregate ranging from fine sand to coarse gravel. Although the material is of variable quality, a number of these deposits are considered important potential aggregate sources.

A small esker containing sand and gravel is located south of Brooke's Bay on Jack Lake. This short sinuous ridge trends in a north to south direction and rises less than 10 feet (3 m) above the surrounding terrain. This esker may have been deposited by meltwater flowing in a tunnel under the ice or in a reentrant at the ice front.

Outwash deposits in this area were laid down by meltwaters flowing from the ice margin. Thicker and more extensive deposits are found in valleys presently occupied by the Crowe River and Eels Creek. About 11 500 years BP, these valleys acted as drainage conduits for water flowing towards the Kawartha Lakes from glacial Lake Algonquin (Chapman and Putnam 1984). Sand is the predominant material exposed in the outwash deposits located in the report area. Thick outwash gravel sequences are only evident in Chandos geographic township, in pits along one section of a tributary of Eels Creek in the northwest and in two deposits in the southeastern part of the township.

As the ice front melted back, glacial lake waters flowed into lower lying areas. Glaciolacustrine plain sediments consisting predominantly of silty fine sand were laid down in shallow waters. These glaciolacustrine sands are generally too fine for most aggregate uses except fill. Glaciolacustrine plain sediments are only found in one deposit in southeastern Methuen geographic township.

Postglacial alluvial sediments, consisting of silt, sand, clay and some fine gravel, are present along the banks of rivers and creeks in the area. In poorly drained areas, swampy and marshy conditions have developed. Organic and recent alluvial sediments are not suitable for use as aggregate.

EXTRACTIVE ACTIVITY

Numerous sand and gravel pits have been opened in the report area, the majority of which are located close to highways. At the time of field investigation, material was being actively extracted from very few pits, however, most of the remaining pits had been worked in recent years. Sand, which is suitable for low specification uses, is the primary material available for extraction. There are an extremely limited number of pits which contain higher specification sand or gravel. Crushable gravel appears to be available from certain deposits only if selective extraction and/or sand control measures are employed.

Quarries have been opened in both the Precambrian and Paleozoic bedrock of the report area. Crushed stone from limestone quarries could potentially compensate for the lack of crushable gravel in this area. Marble may also be a suitable source of crushed stone in this area, however, further testing is necessary. Highly weathered gneisses are being quarried in Methuen geographic township for use on local cottage roads.

SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 1 indicates all of the surficial deposits which contain sand and gravel in the report area. These deposits occupy a total of approximately 6800 acres (2750 ha) and contain an original resource tonnage of 89.1 million tons (80.8 million tonnes). Most of these resources have limited value for reasons of deposit size, thickness and quality of the material. Consequently, only the most significant resource areas are suggested for possible resource protection. The aggregate resources in part of the report area have been previously described by Finamore and Courtney (1982) and Kaszycki (in preparation).

In general, the report area contains limited sand and gravel resources. As a result of this shortage of material, deposits potentially capable of producing at least low specification aggregates, such as Granular Base Course (GBC) C and fill, in locally significant quantities have been considered for possible resource protection. The features selected at the primary and secondary levels of significance are typically shallow in comparison to deposits found in many other areas of Ontario. Bedrock and/or the water table is likely to be encountered within 15 feet (5 m) of the surface in many of the deposits.

The five Selected Sand and Gravel Resource Areas of Primary Significance are outwash and ice-contact deposits. Sand is the predominant material available from these deposits, however, gravel is also present in small quantities. The amount of crushable gravel available is extremely limited, although its extraction and production can be enhanced through the use of selective extraction and/or sand control measures. This gravel is not of the highest quality, but it represents a valuable resource in this gravel deficient area.

The Selected Sand and Gravel Resource Areas of Primary Significance occupy a total available area of 470 acres (190 ha) of which 365 acres (148 ha) are currently available for extraction. They contain possible sand and gravel resources of approximately 7.8 million tons (7.1 million tonnes). The selected areas contain most of the potential resources of quality sand and gravel in the study area.

During field investigation, 14 samples were taken from existing pit and quarry faces, and other exposures. These samples were analysed for grain size distribution (Figures 3a to 7b), and four aggregate quality tests were performed on selected samples. These quality tests included the Los Angeles Abrasion and Impact test, Absorption, and Magnesium Sulphate Soundness test, as well as petrographic analysis. The results of these tests are portrayed in Table 9. The four quality tests were performed by the Soils and Aggregates Section of the Ontario Ministry of Transportation (MTO) in Kingston. Grain size analyses were conducted in either the MTO laboratories or in the Geoscience Laboratory, Ontario Geological Survey.

In general, the aggregate sampled in this area is considered suitable for low specification uses. Most of

the samples are suitable for use as GBC C, and 10 of the samples are suitable for use as GBC B. The amount of crushable gravel is limited and appears only to be available with the use of selective extraction and/or sand control measures. The results of the four quality tests for the most part, fall within MTO specifications for products including GBC A, 5/8 inch (16 mm) crushed stone and Hot-Laid No. 4 stone.

Although the aggregate from this area may meet MTO aggregate testing specifications, based on field performance the local gravels are not accepted by MTO for use in Portland cement concrete which will be exposed to deicing salts. There can be a bonding problem between the cement and the gravel which may eventually result in deterioration of the concrete.

Selected Sand and Gravel Resource Area 1

Selected Sand and Gravel Resource Area 1 consists of four deposits in northeastern Burleigh geographic township. The three outwash deposits which have been designated Resource Area 1a contain four pits. Pit no. 22 is extensive and has 5- to 15-foot (1.5 to 5 m) faces which expose predominantly sand with small pockets of gravel. Material was being extracted from this pit at the time of field investigation. Faces in pit no. 21 expose 6 feet (2 m) of sand with fine to medium gravel. The 6- to 10-foot (2 to 3 m) faces of pit no. 18 reveal less than 2 feet (0.6 m) of fine gravelly sand over silty sand and medium to coarse sand. Selective extraction would be necessary to produce high quality products from this pit. The 6- to 8-foot (2 m) faces of pit no. 20 are sloughed and partially overgrown.

Several test holes have been excavated in the area by MTO to a maximum depth of 12.5 feet (3.8 m). Sand, overlain by layers of gravel 1 to 3 feet (0.3 to 1 m) thick, was exposed in the majority of the holes in the vicinity of pit nos. 20, 21 and 22. MTO indicates that the gravel could be selectively extracted possibly for use as GBC B if the oversize was crushed or removed, or for use as Granular A or 5/8 inch (16 mm) Crushed Type B with heavy sand control. Test holes excavated in the undeveloped area near pit no. 18 revealed predominantly sand which appears to be suitable for pit-run products. Bedrock was encountered at depths between 1.6 and 10.2 feet (0.5 to 3.1 m) in some areas.

Area 1b is an undeveloped ice-contact deposit. A 6-foot (2 m) exposure revealed material varying from fine sand to coarse gravel. A sample taken from this exposure contained 31% gravel, 61% sand and 8% fines (BR-SS-1, Figure 7a). It appears to be suitable for GBC B and C. The depth to bedrock and the depth to the water table appears to be variable in this deposit. Further testing is necessary to determine its potential to supply aggregate.

Selected Resource Area 1 is a potential source of coarse aggregate in an area which generally contains limited amounts of this material. Low specification aggregate is the predominant type of aggregate available from these deposits. Access to Resource Area 1 is provided by a gravel-surfaced road. In the past, material has been extracted from beneath the hydro line which crosses the area. Assuming similar operations are carried out in removing the remaining material, approximately 124 acres (50 ha) are currently available for extraction. Assuming an average deposit thickness of 8 feet (2 m) for all of the deposits, the total available aggregate resources are estimated at 2.5 million tons (2.3 million tonnes).

Selected Sand and Gravel Resource Area 2

Selected Sand and Gravel Resource Area 2 is an ice-contact deposit located in northeastern Anstruther geographic township. Three pits have been developed in this mound-shaped feature. Faces in pit nos. 58, 59 and 60 reveal 6 to 20 feet (2 to 6 m) of material ranging from fine sand to coarse gravel. A sample taken from pit no. 60 contained 28% gravel, 71% sand and 1% fines (Figure 4a). This aggregate appears to be suitable for pit-run uses.

Approximately 17 acres (7 ha) are available for extraction in Resource Area 2 if the extraction of material from beneath the hydro line is allowed to continue. Assuming an average deposit thickness of 12 feet (4 m), sand and gravel resources are estimated to be 0.5 million tons (0.4 million tonnes). Access to the area is provided by a forest access road.

Selected Sand and Gravel Resource Area 3

Six outwash deposits situated along a tributary of Eels Creek in northwestern Chandos geographic township have been selected at the primary level of significance. The three northernmost deposits have been designated as Area 3a and they contain pit nos. 69, 70, 71, 72, 73 and 74. The pits have faces between 5 and 10 feet (1.5 and 3 m) high and expose predominantly fine to medium sand with minor fine gravel and silt. A sample from pit no. 69 contained 6% gravel, 89% sand and 5% fines (Figure 4a). The aggregate in the sample was suitable for GBC B and C and a variety of asphalt products.

Area 3b consists of two gravel deposits and one sand deposit. Pit nos. 67 and 68 have been developed in the gravel deposits. The 5- to 7-foot (1.5 to 2 m) faces reveal predominantly fine to coarse gravel. A sample was taken from pit no. 68 and it contained 38% gravel, 59% sand and 3% fines (Figure 4a). The material in this sample is considered best suited for pit-run products. Gravel in the crushable size range is lacking. However, MTO data indicates that GBC A has been produced from the pit by using selective extraction and sand control measures. Although the gravel found in these deposits is not of the highest quality, the deposits are important because of the lack of gravel sources in the report area. Further

testing in the undeveloped parts of these deposits is necessary to determine the types and amounts of aggregate which are available.

The sand deposit in Resource Area 3b contains pit no. 66. The 6- to 8-foot (2 m) faces in this pit reveal medium to coarse sand which appears suitable for pit-run uses.

Resource Area 3 occupies 237 acres (96 ha) of which approximately 195 acres (79 ha) are available for extraction. Assuming an average thickness of 8 feet (2 m) for both Areas 3a and 3b, sand and gravel resources are estimated to be 3.9 million tons (3.5 million tonnes). The resource area is accessible by forest access roads.

Selected Sand and Gravel Resource Area 4

Selected Sand and Gravel Resource Area 4 consists of an outwash deposit located in southeastern Chandos geographic township. This deposit contains two pits with faces from 8 to 15 feet (2 to 5 m) high. Pit no. 98 reveals silty fine sand to fine gravel, with fine to coarse gravel lenses less than 3 feet (1 m) thick. A sample of the gravelly sand contained 15% gravel, 84% sand and 1% fines (Figure 5a). It appears suitable for GBC B and C and a variety of asphalt products. The faces of pit no. 97 were sloughed at the time of field investigation. MTO data indicates that material from the pit has been used for 5/8 inch (16 mm) crushed Type A, but that sand control was a problem and the material contained a high percentage of oversize clasts.

Resource Area 4 lies in close proximity to Highway 504. It occupies 29 acres (12 ha), of which 24 acres (10 ha) are available for extraction. Based on an average thickness estimate of 10 feet (3 m), sand and gravel resources are approximately 0.6 million tons (0.5 million tonnes).

Selected Sand and Gravel Resource Area 5

An ice-contact deposit in southeastern Chandos geographic township has been selected at the primary level of significance. This mound-shaped deposit contains pit no. 100. The 15- to 20- foot (5 to 6 m) faces expose predominantly medium sand and fine to coarse gravel layers of varying thicknesses. A sample of the gravel contained 37% gravel, 61% sand and 2% fines (Figure 6a). This aggregate is suitable for use as GBC B and C. MTO data for this pit indicates that crushed gravel could be produced from this pit if sand control and selective extraction measures are employed. This source of gravel is valuable in an area where high specification aggregate is not readily available.

Approximately 6 acres (2 ha) are available for extraction in Resource Area 5. Assuming an average deposit depth of 20 feet (6 m), sand and gravel resources are estimated to be 0.3 million tons (0.3 million tonnes). Access to this area is provided by a gravel road branching off Secondary Highway 504.

Resource Areas of Secondary Significance

Several deposits located in Burleigh, Anstruther and Chandos geographic townships have been selected at the secondary level of significance. Although these deposits generally contain finer aggregate than those selected at the primary level, the remaining reserves represent alternative extraction sites.

Two outwash deposits have been classified as secondary resources in southeastern Burleigh geographic township. Pit nos. 3 and 4 both reveal 5 to 15 feet (1.5 to 5 m) of fine to coarse sand which appears suitable for pit-run uses.

In northern Anstruther geographic township, an ice-contact deposit has been selected at the secondary level of significance. A pit opened in this deposit, to the north in adjacent Monmouth Township, exposes 6 to 10 feet (1.8 to 3 m) of medium sand with minor clasts ranging in size from fine gravel to boulders. The aggregate appears suitable for pit-run uses (Ontario Geological Survey 1988). This deposit is not easily accessible through Anstruther geographic township.

A sand outwash deposit has also been selected at the secondary level in eastern Anstruther geographic township. Pit nos. 50, 51, 52 and 53 have been developed in this feature. The 5- to 10-foot (1.5 to 3 m) pit faces reveal predominantly silty to clean, fine to coarse sand with pockets of fine gravel. A sample of gravel from pit no. 52 contains 36% gravel, 61% sand and 3% fines, and appears suitable for GBC B and C (Figure 3a). Available reserves in this deposit may be limited, as indicated by the presence of bedrock in several places in the floor of pit nos. 50 and 52.

Secondary areas in Chandos geographic township consist of two outwash deposits. The deposit located near Glen Alda in eastern Chandos geographic township contains one pit. The faces of pit no. 92 expose 10 feet (3 m) of fine to medium sand with minor amounts of fine gravel. A sample taken contained 98% sand and 2% fines, which appears suitable for GBC C and fill (Figure 5a). This deposit is fairly extensive, and test holes excavated by MTO in the undeveloped area revealed at least 12 feet (4 m) of fine sand. The second outwash deposit is situated in southeastern Chandos geographic township. Pit no. 101 is located in this feature and has 10- to 20-foot (3 to 6 m) faces which expose mainly fine to medium sand. MTO excavated 3 test holes in this deposit, to depths of 15 feet (5 m). Pockets of gravel were exposed but further testing is necessary to determine the amount of crushable material available.

BEDROCK GEOLOGY

The report area is predominantly underlain by Precambrian rocks of the Grenville Province of the Canadian

Shield. The bedrock geology of the area is portrayed at a reconnaissance level in Figure 2. Geological maps and reports by Adams and Barlow (1910), Bartlett et al. (1982), Bright (1981a, 1981b and 1988), Carson (1980a and 1980b), Hewitt (1962), Lumbers (1978) and Shaw (1962) cover most of the report area.

The area is located in the Central Metasedimentary Belt of the Grenville Province (Wynne-Edwards 1972). This Belt contains metavolcanics and metasedimentary rocks of a low metamorphic grade. The metasediments, dominant in the report area, are intensely folded and have been intruded by batholiths (Bright 1988). The bedrock geology of Anstruther and northwestern Burleigh geographic townships is dominated by two plutons consisting predominantly of leucocratic and hybrid granite gneiss, pegmatitic granite and granitic pegmatite. The remainder of the report area is predominantly underlain by marble with granitic and syenitic rocks, paragneiss, para-amphibolite and gabbro (Hewitt 1962).

The Precambrian bedrock within the report area may exhibit wide variations with respect to aggregate quality over relatively short distances. Some of the coarse-grained rocks with high mica, quartz and feldspar contents may have bonding problems because the smooth cleavage and fracture surfaces of these minerals hinder the adhesion of asphalt and cement mixes. Eroding the smooth surfaces by stockpile weathering or the addition of chemicals (anti- stripping agents) may result in better adhesion. It is possible that the Precambrian rocks in the report area, particularly the granites, may be alkali-reactive and may not be accepted by the MTO for use in cement concrete (Rogers 1985). Consequently, any site that may be proposed for aggregate extraction should be thoroughly investigated before development occurs.

Marble has been quarried in two locations, one in each of Chandos and Burleigh geographic townships (Map 3). The 10- to 15- foot (3 to 5 m) faces in quarry nos. 2 and 3 expose mainly banded, medium- to coarse-grained marble. Testing is required to establish the suitability of this stone for use in crushed stone products. Quarry no. 13, in Methuen geographic township, has also been opened in metasedimentary rocks. The 10- to 15-foot (3 to 5 m) faces reveal predominantly probable metaconglomerate and meta-arenite. This material does not appear to be suitable for high quality aggregate, however, it may be suitable for low specification uses.

An important source of aggregate in Methuen geographic township is weathered gneiss. This gneiss has been weathered to the degree that it now has the consistency of sand. This material has been extracted from quarry nos. 4 through 12 and 14 through 18, which have face heights ranging from 4 to 8 feet (1 to 2 m). A sample taken from quarry no. 11 contained 99% sand and 1% fines and appears suitable for use as GBC B and C, as well as some asphaltic products (Figures 7a and 7b). The aggregate tends to be so clean (i.e., lacks fines) that fines may have to be added to act as a binder to ensure proper compaction of the material for GBC B and C. The material appears to be used predominantly for the construction and maintenance of local cottage roads.

A large outcrop of nepheline syenite in central Methuen geographic township between the communities of Nephton and Blue Mountain has been extensively mined. The open pit mines in this area have face heights ranging from 40 to 160 feet (12 to 49 m). The nepheline syenite is being used primarily for glass manufacturing.

Paleozoic bedrock is found in southwestern Methuen geographic township, and in four outliers in southern Burleigh and Methuen geographic townships. The oldest Paleozoic formation, the Shadow Lake Formation, lies unconformably atop the Precambrian basement in some areas. The formation consists of predominantly red and green shales, siltstones and sandstones (Carson 1980a, 1980b). The thickness of this unit can reach approximately 59 feet (18 m) (Carson 1980a) in the Peterborough area, however, it is generally less than 15 feet (5 m) thick in the study area. Although the Shadow Lake Formation is a potential source of decorative stone, it has very limited value as an aggregate source, and does not appear to be suitable for any aggregate products in this area.

The Shadow Lake Formation is overlain by the Gull River Formation. The Gull River Formation consists of pale grey to pale and medium brown and brown-grey, lithographic to fine-grained, thickly bedded to massive limestone (Carson 1980a, 1980b). The formation thickness in the study area generally averages less than 60 feet (18 m). Although rocks in certain layers have proven to be alkali-reactive when used in Portland cement concrete, the limestone of this formation is generally suitable for a wide range of crushed stone products. For this reason these thinly drift-covered limestones have been selected for possible resource protection.

The limestones of the Bobcaygeon Formation overlie the Gull River Formation. The lower portions of the Bobcaygeon Formation consist predominantly of medium to dark grey or brown or grey- brown, fine-to medium-grained, locally nodular limestone. Brown, fine- to medium-grained, bioclastic limestones with shaly partings are found in the upper portions of the Bobcaygeon Formation (Carson 1980b). The Bobcaygeon Formation is estimated to be approximately 5 feet (1.5 m) thick in the study area. Aggregate can be produced from the Bobcaygeon Formation and therefore the formation has been selected for potential protection where it occurs in the study area.

Selected Bedrock Resource Areas 1 and 2

Selected Bedrock Resource Areas 1 and 2 consist of the Gull River Formation, designated as Areas 1a through 1e, and the Bobcaygeon Formation, designated as Areas 2a through 2c. Drift cover over the limestones is generally limited to 25 feet (8 m) in both Burleigh and Methuen geographic townships. Two quarries have been developed in the Resource Areas. Quarry no. 1 is

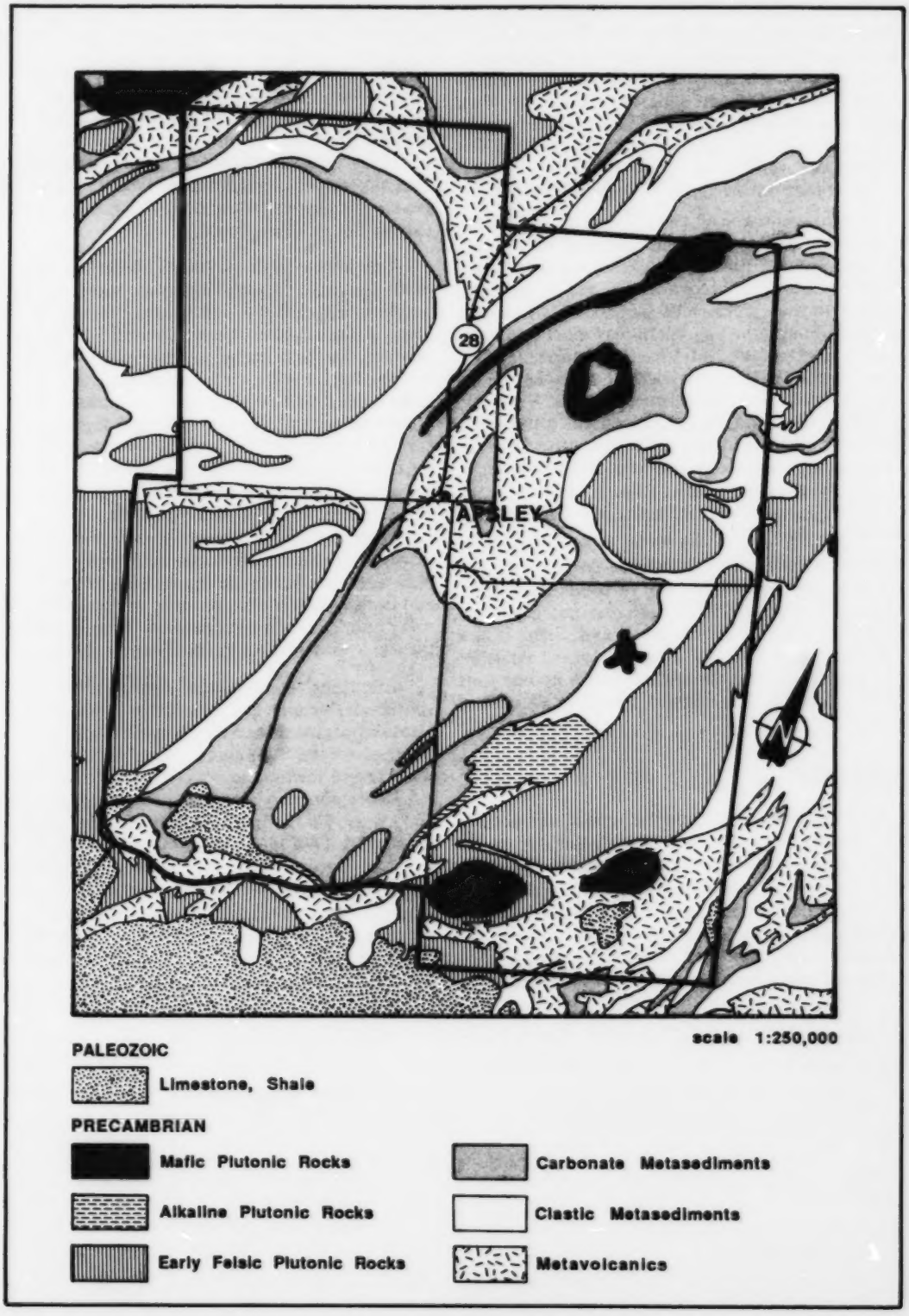


Figure 2. Bedrock geology of Burleigh and Anstruther Township, Chandos Township and Methuen geographic township. *After* Ontario Geological Survey (1991).

located in Area 1b in the Gull River Formation in southern Burleigh geographic township. The 10- to 15-foot (3 to 5 m) faces of the quarry reveal thin to thick bedded, brown-grey limestone. Quarry no. 20 has been developed in southern Methuen geographic township. Face heights range from 15 to 20 feet (5 to 6 m) and expose medium to thick bedded, grey limestone of the Gull River Formation, overlain by up to 5 feet (1.5 m) of brown-grey limestone of the Bobcaygeon Formation.

A sample was taken of the Gull River Formation limestone from quarry no. 20 and submitted for four aggregate quality tests. Based on the results of these tests, the stone appears suitable for a wide range of aggregate products, with the exception of Hot-Laid No.1 asphalt (Table 9). Although the aggregate may meet specifications, certain beds of the Gull River Formation may contain alkali-carbonate reactive rocks and may not be accepted by MTO for use in concrete aggregate. Similarly, the Bobcaygeon Formation may contain alkali-silica reactive rocks which also may not be acceptable for use in concrete aggregate. To alleviate these problems, MTO suggests either selective extraction to avoid reactive beds, or dilution of the aggregate with non-reactive rocks (Rogers 1985).

The Selected Bedrock Resource Areas cover approximately 4600 acres (1860 ha) of which 4000 acres (1620 ha) are available for extraction. Assuming an average workable thickness of between 15 and 60 feet (5 and 18 m) for Area 1 and 5 feet (1.5 m) for Area 2, available bedrock resources are estimated to be 630 million tons (570 million tonnes). The resource areas are all accessible by road.

SUMMARY

The sand and gravel deposits in the report area are the product of glacial processes which took place during the Late Wisconsinan Substage of the Pleistocene Epoch. A number of these deposits which contain significant resources of sand and gravel have been grouped into five primary resource areas. Several deposits of variable aggregate quality also have been selected at the secondary level of significance to augment the primary resource areas. Care should be taken to ensure the continued availability of as much of the resource areas as possible.

The most common deposits in the report area are shallow accumulations of outwash sand located predominantly in Chandos geographic township. This material is generally suitable for low specification aggregate uses. Gravel is found in a small number of outwash deposits and ice-contact deposits. Supplies of crushable gravel are lacking throughout the report area, and it usually has to be imported.

The report area is mainly underlain by Precambrian-age rock although Paleozoic rocks occur along the southern edge of the report area, usually as outliers. Two quarries have been opened in Precambrian marbles, one in Burleigh geographic township and one in Chandos geographic township. Several small quarries have been developed in highly weathered gneisses in Methuen geographic township and the material they supply is generally used for local cottage roads. The Paleozoic limestones of the Gull River and Bobcaygeon formations have been selected as primary bedrock resource areas. Crushed stone from the thinly drift-covered limestone beds appears to be suitable for a wide range of aggregate products. Although this aggregate may meet specifications, certain beds of the Gull River and Bobcaygeon formations may contain alkali-reactive rocks and for this reason may not be accepted by MTO for use in concrete aggregate (Rogers 1985).

Enquiries regarding the Aggregate Resources Inventory of Burleigh and Anstruther Township, Chandos Township and Methuen Geographic Township should be directed to the Aggregate Assessment Office, Engineering and Terrain Geology Section, Ontario Geological Survey, Ontario Ministry of Northern Development and Mines, 7th Floor, 77 Grenville Street, Toronto, Ontario M7A 1W4 [Telephone (416) 965-1663] or to the Resident Geologist, Ontario Ministry of Northern Development and Mines, Bag Service 43, Old Troy Road, Tweed, Ontario, K0K 3J0 [Telephone (613) 478-2330] or to the Bancroft District Office, Ontario Ministry of Natural Resources, P.O. Box 500, Hwy. 28, Bancroft, Ontario, K0L 1C0 [Telephone (613) 332-3940].

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.[1,2]

1 CLASS NO.	2 DEPOSIT TYPE (*see* Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE[3] Millions of Tons (Tonnes)
Burleigh Geographic Township			
3	S-E	7 (3)	0.1 (0.1)
	S-IC	20 (8)	0.4 (0.4)
	S-OW	340 (138)	6.4 (5.8)
4	S-OW	142 (58)	1.4 (1.3)
		510 (206)	8.3 (7.5)
Anstruther Geographic Township			
2	S-IC	21 (8)	0.6 (0.5)
	S-OW	16 (6)	0.6 (0.5)
3	S-IC	49 (20)	0.8 (0.7)
	S-OW	150 (61)	1.9 (1.7)
4	S-IC	10 (4)	0.1 (0.1)
	S-OW	500 (202)	5.0 (4.5)
		750 (305)	9.0 (8.2)
Chandos Geographic Township			
2	G-IC	7 (3)	0.4 (0.4)
	S-OW	198 (80)	6.1 (5.5)
3	G-OW	97 (39)	1.9 (1.7)
	S-OW	1310 (530)	24.1 (21.9)
4	S-OW	3650 (1480)	36.2 (32.8)
		5300 (2140)	68.7 (62.3)
Methuen Geographic Township			
3	G-OW	22 (9)	0.3 (0.3)
	S-OW	45 (18)	0.7 (0.6)
4	S-LP	8 (3)	<0.1 (<0.1)
	S-OW	209 (84)	2.1 (1.9)
		285 (115)	3.1 (2.8)
TOTAL FOR STUDY AREA:		6800 (2750)	89.1 (80.8)

[1] *Identified deposit areas within Petroglyphs Provincial Park and Kawartha Highlands Park Reserve have been omitted on all tables.*

[2] *For clarity, the information is cited in all tables on the basis of geographic townships. The relationships between the geographic townships and the municipal townships are explained in the text (see Location and Population Section).*

[3] *For practical purposes, the Original Tonnage figures for this report area have been shown to the nearest decimal place, because of the small amount of material present in some deposits.*

N.B. Minor variations in all tables are caused by rounding of data.

TABLE 2. SAND AND GRAVEL PITS, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

1 NO.	2 MTO NO.	3 LOT	4 CONC.	5 FACE HEIGHT Feet (Metres)	6 % GRAVEL	7 REMARKS
Burleigh Geographic Township						
1	–	6	12S	–	–	overgrown
2	–	6	12S	6–7 (2)	< 10	fine to medium sand, bedrock exposed in floor and face
3	–	3	11S	5–15 (1.5–5)	< 10	mainly fine to coarse sand
4	–	3	10S	8–12 (2–4)	–	fine to medium sand, bedrock exposed in floor and face, partially overgrown
5	–	3	10S	5 (1.5)	–	fine sand, bedrock exposed in face and floor, partially overgrown
6	–	3	7S	8 (2)	–	till
7	–	2	7S	10–15 (3–5)	–	till draping rock
8	–	4	5S	6 (2)	–	till
9	–	4	5S	< 5 (< 1.5)	–	till
10	–	3	4S	< 5 (< 1.5)	–	till
11	–	5	3S	5 (1.5)	< 20	depleted, extracted to bedrock
12	–	5	3S	6–10 (2–3)	< 20	depleted, extracted to bedrock, water on floor
13	–	9	3S	8 (2)	–	till
14	–	9	3S	6–8 (2)	< 20	bedrock exposed in face, water on floor
15	–	1	8N	< 5 (< 1.5)	–	sand, water on floor, partially overgrown
16	–	1	8N	4–6 (1–2)	–	sand against bedrock, partially overgrown
17	–	2	8N	< 5 (< 1.5)	< 5	bedrock exposed in face, water on floor, partially overgrown
18	–	3	15N	6–10 (2–3)	< 5	medium to coarse sand, water on floor, bedrock exposed in face and floor
19	–	4	15N	10–12 (3–4)	< 5	fine to coarse sand, water on floor

TABLE 2. SAND AND GRAVEL PITS, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

1 NO.	2 MTO NO.	3 LOT	4 CONC.	5 FACE HEIGHT Feet (Metres)	6 % GRAVEL	7 REMARKS
20	–	4	15N	6–8 (2)	–	sand, partially overgrown
21	B9–40–0	5	15N	6 (2)	< 20	bedrock exposed in floor and face, water on floor
22	B9–40–0	6	15N	5–15 (1.5–5)	variable	sand with pockets of gravel, bedrock exposed in places in the floor and faces, water on floor
23	–	5	15N	8 (2)	–	sand, overgrown
24	–	6	15N	10 (3)	–	sand, bedrock exposed in face and floor, depleted
25	–	12	16N	4–10 (1–3)	variable	mainly coarse sand
26	–	14	16N	10–15 (3–5)	–	till
27	–	15	16N	8–20 (2–6)	–	till flanking bedrock
28	–	16	15N	10 (3)	–	till
29	B9–11	13	12N	–	–	overgrown
30	–	15	10N	10–15 (3–5)	–	fine sand against bedrock
31	–	19	12N	6–7 (2)	< 35 variable	mainly fine sand, bedrock in floor and faces, water on floor
32	–	20	13N	4–6 (1–2)	< 5	fine sand, bedrock exposed in face
33	B9–7	20	13N	10 (3)	< 10	fine sand against bedrock
34	–	23	13N	10 (3)	< 10	fine sand against bedrock
35	–	23	13N	7 (2)	–	mainly fine silty sand, bedrock in face, water on floor, partially overgrown
36	–	23	13N	8–10 (2–3)	< 10	mainly fine silty sand against bedrock
Anstruther Geographic Township						
37	–	32	1	25 (8)	–	sand draping bedrock, depleted
38	–	32	1	< 5 (< 1.5)	–	sand, overgrown

TABLE 2. SAND AND GRAVEL PITS, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

1 NO.	2 MTO NO.	3 LOT	4 CONC.	5 FACE HEIGHT Feet (Metres)	6 % GRAVEL	7 REMARKS
39	–	31	1	< 5 (< 1.5)	–	fine sand, bedrock exposed in face and floor, partially overgrown
40	–	30	1	< 5 (< 1.5)	< 10	fine to medium sand, bedrock exposed in floor
41	–	18	1	10–12 (3–4)	–	till
42	–	19	2	8 (2)	–	till
43	–	17	2	20–25 (6–8)	–	till draping bedrock
44	–	11	2	8–10 (2–3)	–	till
45	–	8	2	5 (1.5)	–	till, overgrown
46	–	1	3	6–7 (2)	–	till
47	–	34	5	6 (2)	–	fine to medium sand, partially overgrown
48	G3–22	35	6	8 (2)	< 20	partially overgrown
49	–	35	7	8–10 (2–3)	–	till
50	G3–21–0	38	8	6–8 (2)	< 15	water on floor, bedrock exposed in floor
51	G3–21–0	38	8	6–10 (2–3)	< 15	medium to coarse sand over silty fine sand
52	G3–21–0	38	8	6–10 (2–3)	< 20	water on floor, bedrock exposed in floor and face
53	G3–20–0	39	8	5–8 (1.5–2)	–	overgrown
54	G3–44–0	38	11	15–20 (5–6)	< 5	silty fine sand, till exposed in one face, water on floor
55	–	38	11	5–6 (1.5–2)	–	sand, partially overgrown
56	–	26	15	5–6 (1.5–2)	< 30	coarse sand with fine to coarse gravel
57	–	19	15	5–6 (1.5–2)	variable	bedrock exposed in floor
58	–	27	15	8 (2)	15–25	partially overgrown

TABLE 2. SAND AND GRAVEL PITS, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

1 NO.	2 MTO NO.	3 LOT	4 CONC.	5 FACE HEIGHT Feet (Metres)	6 % GRAVEL	7 REMARKS
59	–	27	15	6–20 (2–6)	variable	fine sand to coarse gravel
60	–	28	15	8–15 (2–5)	variable	3-foot (1 m) thick gravel lens
61	–	28	16	5–10 (1.5–3)	variable	water on floor, bedrock exposed in face and floor
62	–	28	16	< 5 (< 1.5)	< 20	mainly medium to coarse sand
63	–	30	16	5–15 (1.5–5)	< 10	silty to coarse sand, bedrock exposed in face
64	–	30	16	< 5 (< 1.5)	35–40	bedrock exposed in floor, partially overgrown
Chandos Geographic Township						
65	G3–58–0	2	18	6–10 (2–3)	< 10	silty to fine sand
66	–	1	13	6–8 (2)	< 20	water on floor, partially overgrown
67	G3–45–0	2	13	6–7 (2)	30–50	water on floor, partially overgrown
68	G3–55–0	4	14	5–6 (1.5–2)	30–50	water on floor, partially overgrown
69	–	10	15	6–8 (2)	< 10	sand with silty sand layers
70	G3–62–0	11	15	8 (2)	< 15	sand with lenses of silty sand
71	G–62–0	11	15	8–10 (2–3)	< 15	sand with lenses of silty sand
72	G3–62–0	11	15	5 (1.5)	< 10	partially overgrown
73	G3–62–0	12	15	5 (1.5)	< 15	bedrock exposed in floor, partially overgrown
74	–	14	16	6 (2)	< 10	water on floor, partially overgrown
75	G3–48	20	13	6 (2)	–	sand, overgrown
76	–	20	13	7 (2)	< 10	mainly fine to medium sand, bedrock exposed in face
77	G3–56–0	19	12	6–8 (2)	< 10	silty fine to medium sand
78	–	14	12	< 5 (< 1.5)	–	till

TABLE 2. SAND AND GRAVEL PITS, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

1 NO.	2 MTO NO.	3 LOT	4 CONC.	5 FACE HEIGHT Feet (Metres)	6 % GRAVEL	7 REMARKS
79	G3-60-0	16	11	15 (5)	-	fine sand draping bedrock, depleted
80	G3-60-0	16	11	20 (6)	-	fine sand draping bedrock, depleted
81	-	14	10	6 (2)	variable	silt lenses
82	-	3	8	10 (3)	variable	
83	G3-3-0	2	7	5-12 (1.5-4)	variable	lenses of gravel
84	G3-3-0	2	7	6 (2)	< 10	bedrock exposed in face and floor, water on floor
85	-	1	7	6-7 (2)	variable	bedrock exposed in faces
86	G3-3-0	2	7	6 (2)	-	sand, water on floor, overgrown
87	-	8	7	8-10 (2-3)	-	till
88	-	17,18	9	< 5 (< 1.5)	-	depleted, extracted to bedrock
89	-	18	9	< 5 (< 1.5)	-	overgrown, depleted, extracted to bedrock
90	-	28	9	8 (2)	-	sand, bedrock exposed in face and floor, partially overgrown
91	C10-35-0	32	9	< 5 (< 1.5)	-	sand, depleted
92	C10-51-0	32	8	10 (3)	< 10	fine to medium sand with minor amounts of fine gravel, water on floor
93	C10-29-0	30	8	8-10 (2-3)	< 5	water on floor, overgrown
94	-	27	6	10-12 (3-4)	< 10	fine sand
95	-	23	6	8-10 (2-3)	0-15	mainly fine to medium sand
96	C10-41-0	20	4	15-20 (5-6)	< 25	faces sloughed, flanking bedrock
97	C10-15-0	20	3	8-12 (2-4)	-	faces sloughed and overgrown

TABLE 2. SAND AND GRAVEL PITS, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

1 NO.	2 MTO NO.	3 LOT	4 CONC.	5 FACE HEIGHT Feet (Metres)	6 % GRAVEL	7 REMARKS
98	-	20	3	8–15 (2–5)	variable	multiple faces reveal fine sand and sand with gravel
99	-	20	3	10–15 (3–5)	< 15	mainly gravelly sand, partially overgrown
100	C10–2–0	26	3	15–20 (5–6)	variable	medium sand and fine to coarse gravel layers
101	C10–1–0	22	2	10–20 (3–6)	< 20	mainly fine to medium sand
102	-	20	2	6–15 (2–5)	< 10	fine to medium sand
103	-	18	2	15–20 (5–6)	-	faces graded
104	-	17	2	8 (2)	< 20	fine to coarse sand
Methuen Geographic Township						
105	-	31	8	5 (1.5)	< 5	fine silty sand, water on floor
106	-	31	9	< 5 (< 1.5)	< 5	silty fine to medium sand
107	-	31	10	4–8 (1–2)	< 5	fine silty sand, bedrock exposed in the floor and face
108	-	31	11	< 5 (< 1.5)	< 5	fine silty sand
109	-	28	11	8–10 (2–3)	-	till
110	-	22	8	< 5 (< 1.5)	< 5	fine silty sand, bedrock exposed in faces
111	-	24	5	6 (2)	variable	one section shows sandy gravel, water on floor, partially overgrown
112	-	2	6	7–8 (2)	< 10	sand, water on floor, bedrock exposed in floor
113	-	2	6	6 (2)	-	fine sand, bedrock exposed in face, partially overgrown

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

1 DEPOSIT NO.	2 AREA Acres (Hectares)	3 CULTURAL SETBACKS Acres (Hectares)	4 EXTRACTED AREA Acres (Hectares)	5 AVAILABLE AREA Acres (Hectares)	6 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	7 AVAILABLE AGGREGATE[1] Millions of Tons (Tonnes)
Burleigh Geographic Township						
1a	156 (63)	0 (0)	52 (21)	104 (42)	8 (2)	2.1 (1.9)
1b	20 (8)	0 (0)	0 (0)	20 (8)	8 (2)	0.4 (0.4)
	176 (71)	0 (0)	52 (21)	124 (50)		2.5 (2.3)
Anstruther Geographic Township						
2	21 (8)	0 (0)	4 (2)	17 (7)	12 (4)	0.5 (0.4)
Chandos Geographic Township						
3a	105 (42)	0 (0)	10 (4)	95 (38)	8 (2)	1.9 (1.7)
3b	132 (53)	0 (0)	32 (13)	100 (40)	8 (2)	2.0 (1.8)
	237 (96)	0 (0)	42 (17)	195 (79)		3.9 (3.5)
4	29 (12)	0 (0)	5 (2)	24 (10)	10 (3)	0.6 (0.5)
5	7 (3)	0 (0)	1 (< 1)	6 (2)	20 (6)	0.3 (0.3)
	275 (111)	0 (0)	48 (19)	225 (91)		4.8 (4.4)
Methuen Geographic Township		- NONE -				
TOTAL FOR STUDY AREA:						
	470 (190)	0 (0)	104 (42)	365 (148)		7.8 (7.1)

[1] *For practical purposes, the Available Aggregate figures for this project area have been shown to the nearest decimal place, because of the small amount of material present in some deposits.*

TABLE 4. TOTAL IDENTIFIED BEDROCK RESOURCES[1], BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

1 DRIFT THICKNESS Feet (Metres)	2 FORMATION	3 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	4 AREAL EXTENT Acres (Hectares)	5 ORIGINAL TONNAGE Millions of Tons (Tonnes)
Burleigh Geographic Township				
3–25 (1–8)	Shadow Lake	5–10 (1.5–3)	138 (56)	4 (4)
3–25 (1–8)	Gull River[2]	15–60 (5–18)	3250 (1320)	600 (540)
3–25 (1–8)	Bobcaygeon	5 (1.5)	102 (41)	2 (2)
			3500 (1420)	610 (550)
Anstruther Geographic Township				
		- NONE -		
Chandos Geographic Township				
		- NONE -		
Methuen Geographic Township				
3–25 (1–8)	Shadow Lake	10–15 (3–5)	56 (23)	2 (2)
3–25 (1–8)	Gull River[2]	20–30 (6–9)	1160 (470)	106 (96)
3–25 (1–8)	Bobcaygeon	5 (1.5)	74 (30)	1 (< 1)
			1290 (520)	109 (99)
TOTAL FOR STUDY AREA:			4800 (1940)	720 (650)

[1] *The Precambrian bedrock within the report area may exhibit wide variations with respect to aggregate quality over relatively short distances, and therefore it is not possible to identify specific potential Precambrian bedrock resources for aggregate in a study of this scope. For this reason, this table refers only to Paleozoic bedrock resources. Precambrian bedrock resources are discussed in the text (see Bedrock Geology Section).*

[2] *Calculations for the areal extent of the Gull River Formation include that area which is overlain by the Bobcaygeon Formation.*

TABLE 5. QUARRIES, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

1 NO.	2 MTO NO.	3 LOT	4 CONC.	5 FACE HEIGHT Feet (Metres)	6 REMARKS
Burleigh Geographic Township					
1	–	7	4S	10–15 (3–5)	limestone
2	–	6	15N	10 (3)	marble and some gneiss
Anstruther Geographic Township					
			– N O N E –		
Chandos Geographic Township					
3	–	–	D	10–15 (3–5)	marble, water on floor
Methuen Geographic Township					
4	–	31	7	< 5 (< 1.5)	weathered gneiss
5	–	25,26	4	6 (2)	weathered gneiss, partially overgrown
6	–	24	4	6–8 (2)	weathered gneiss
7	–	23	3	< 5 (< 1.5)	weathered gneiss
8	–	16	2	6–8 (2)	weathered gneiss
9	–	16	3	6–8 (2)	weathered gneiss, overgrown
10	–	17	4	4–8 (1–2)	weathered gneiss, partially overgrown
11	–	18	5	5 (1.5)	weathered gneiss
12	–	19	5	8 (2)	weathered gneiss
13	–	11	9	10–15 (3–5)	mainly metaconglomerate and meta–arenite
14	–	12	9	< 5 (< 1.5)	weathered gneiss
15	–	11	8	< 5 (< 1.5)	weathered gneiss
16	–	10	7	8 (2)	weathered gneiss
17	–	13	6	< 5 (< 1.5)	weathered gneiss
18	–	14	5	6 (2)	weathered gneiss
19	–	6	5	15–18 (5–6)	shale and limestone
20	B2–48–0	4	5	15–20 (5–6)	limestone

TABLE 6. SELECTED BEDROCK RESOURCE AREAS, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED WORKABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)
Burleigh Geographic Township							
Gull River Formation[1]							
1a	3–25 (1–8)	600 (243)	60 (24)	0 (0)	540 (218)	15 (5)	29 (26)
1b	3–25 (1–8)	2650 (1070)	249 (101)	1 (< 1)	2400 (970)	60 (18)	520 (470)
		3250 (1320)	310 (125)	1 (< 1)	2950 (1190)		550 (500)
Bobcaygeon Formation							
2a	3–25 (1–8)	62 (25)	12 (5)	0 (0)	50 (20)	5 (1.5)	< 1 (< 1)
2b	3–25 (1–8)	40 (16)	6 (2)	0 (0)	50 (14)	5 (1.5)	< 1 (< 1)
		102 (41)	18 (7)	0 (0)	84 (34)		< 1 (< 1)
		3350 (1360)	330 (134)	1 (< 1)	3050 (1230)		550 (500)
Anstruther Geographic Township			- NONE -				
Chandos Geographic Township			- NONE -				
Methuen Geographic Township							
Gull River Formation[1]							
1c	3–25 (1–8)	250 (101)	30 (12)	0 (0)	220 (89)	30 (9)	24 (22)
1d	3–25 (1–8)	720 (290)	189 (76)	1 (< 1)	530 (214)	25 (8)	48 (44)
1e	3–25 (1–8)	193 (78)	43 (17)	0 (0)	150 (61)	20 (6)	11 (10)
		1160 (470)	260 (105)	1 (< 1)	900 (365)		83 (75)
Bobcaygeon Formation							
2c	3–25 (1–8)	74 (30)	6 (2)	1 (< 1)	67 (27)	5 (1.5)	1 (< 1)
		1230 (500)	265 (107)	2 (< 1)	970 (395)		84 (76)
TOTAL FOR STUDY AREA:		4600 (1860)	600 (243)	3 (1)	4000 (1620)		630 (570)

[1] *Calculations for the areal extent of the Gull River Formation include that area which is overlain by the Bobcaygeon Formation.*

TABLE 7. SUMMARY OF TEST HOLE DATA, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

-NONE-

TABLE 8. SUMMARY OF GEOPHYSICS DATA, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

-NONE-

TABLE 9. RESULTS OF AGGREGATE QUALITY TESTS, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

	COARSE AGGREGATE					FINE AGGREGATE
	Petrographic Number					
Sample No.	Granular & 16 mm Crushed	Hot Mix & Concrete	Magnesium Sulphate Soundness (% Loss)	Absorption (%)	Los Angeles Abrasion (% Loss)	Magnesium Sulphate Soundness (% Loss)
Pit 60	100	119	10	–	–	11
Pit 68	102	133	–	0.90	–	14
Pit 83	101	116	22	0.64	–	23
Pit 100	101	118	14	0.57	–	12
BR-SS-1	100	134	19	–	–	20
BR-SS-2	102	131	–	–	–	8
Quarry 20	100	102	4	–	27	8

NOTE: The quality refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits, care should be exercised in extrapolating such information to the rest of the deposit.

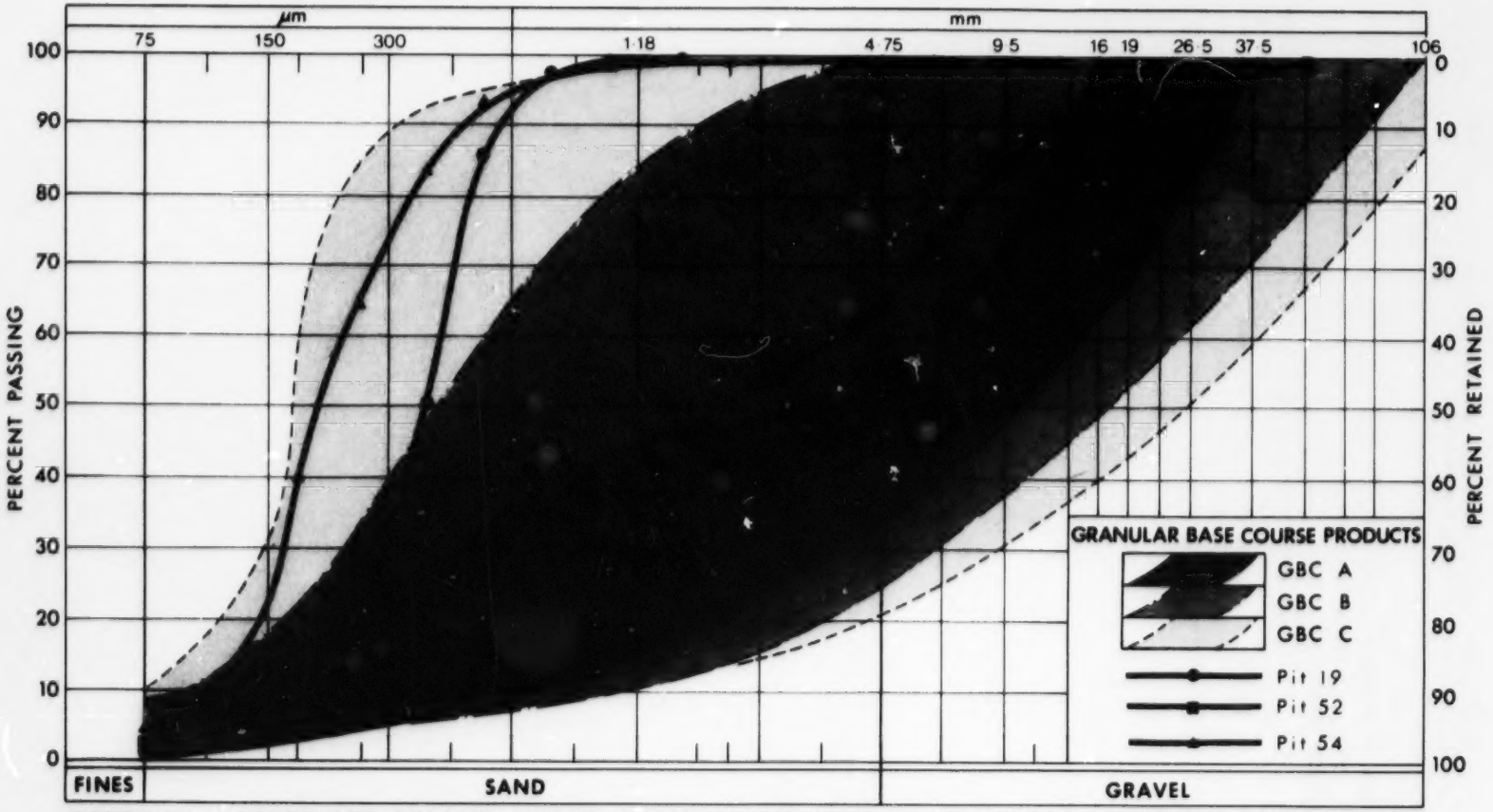


FIGURE 3a. AGGREGATE GRADING CURVES, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Form 1010, 1980).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

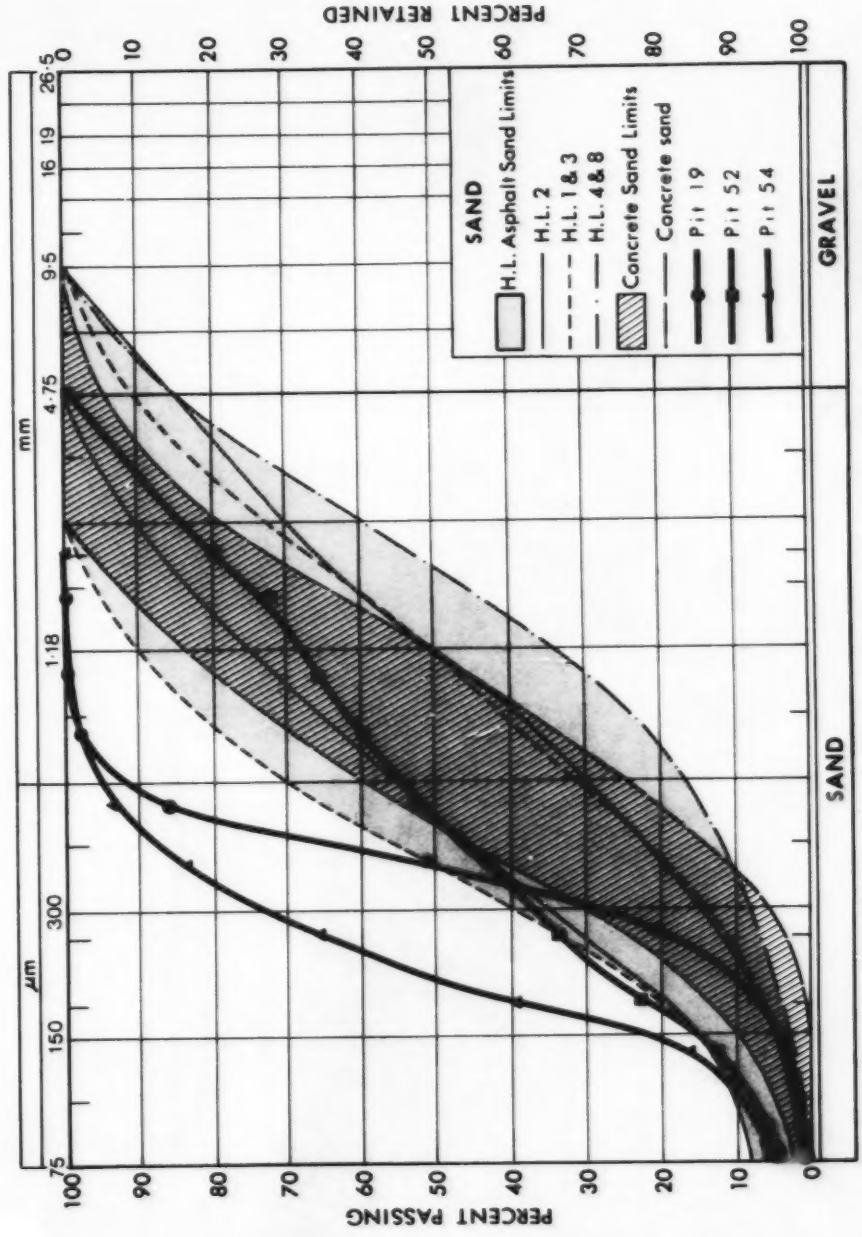


FIGURE 3b. AGGREGATE GRADING CURVES, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Forms 1002, 1979 and 1003, 1981).

NOTE: Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

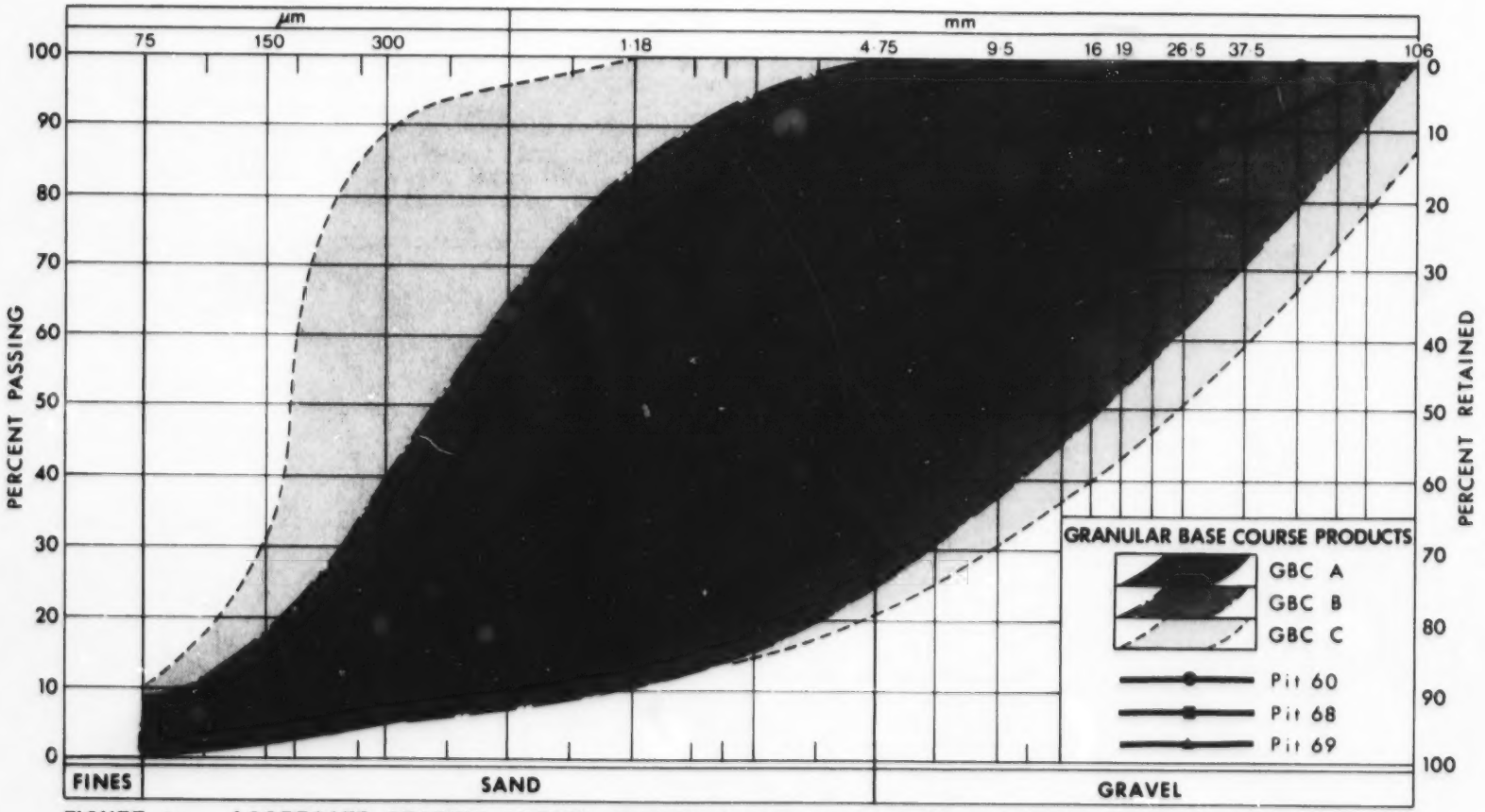


FIGURE 4a. AGGREGATE GRADING CURVES, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Form 1010, 1980).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

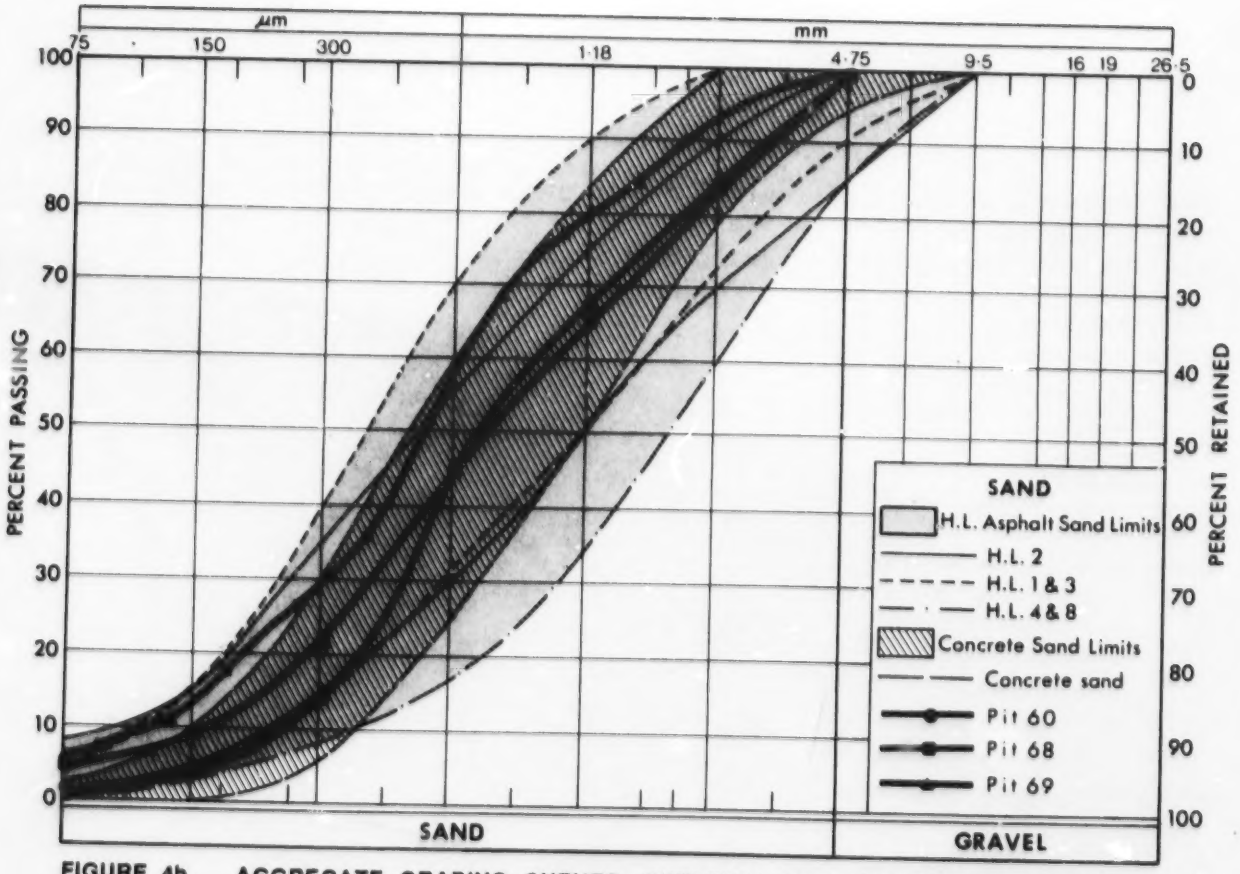


FIGURE 4b. AGGREGATE GRADING CURVES, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Forms 1002, 1979 and 1003, 1981).

NOTE: Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

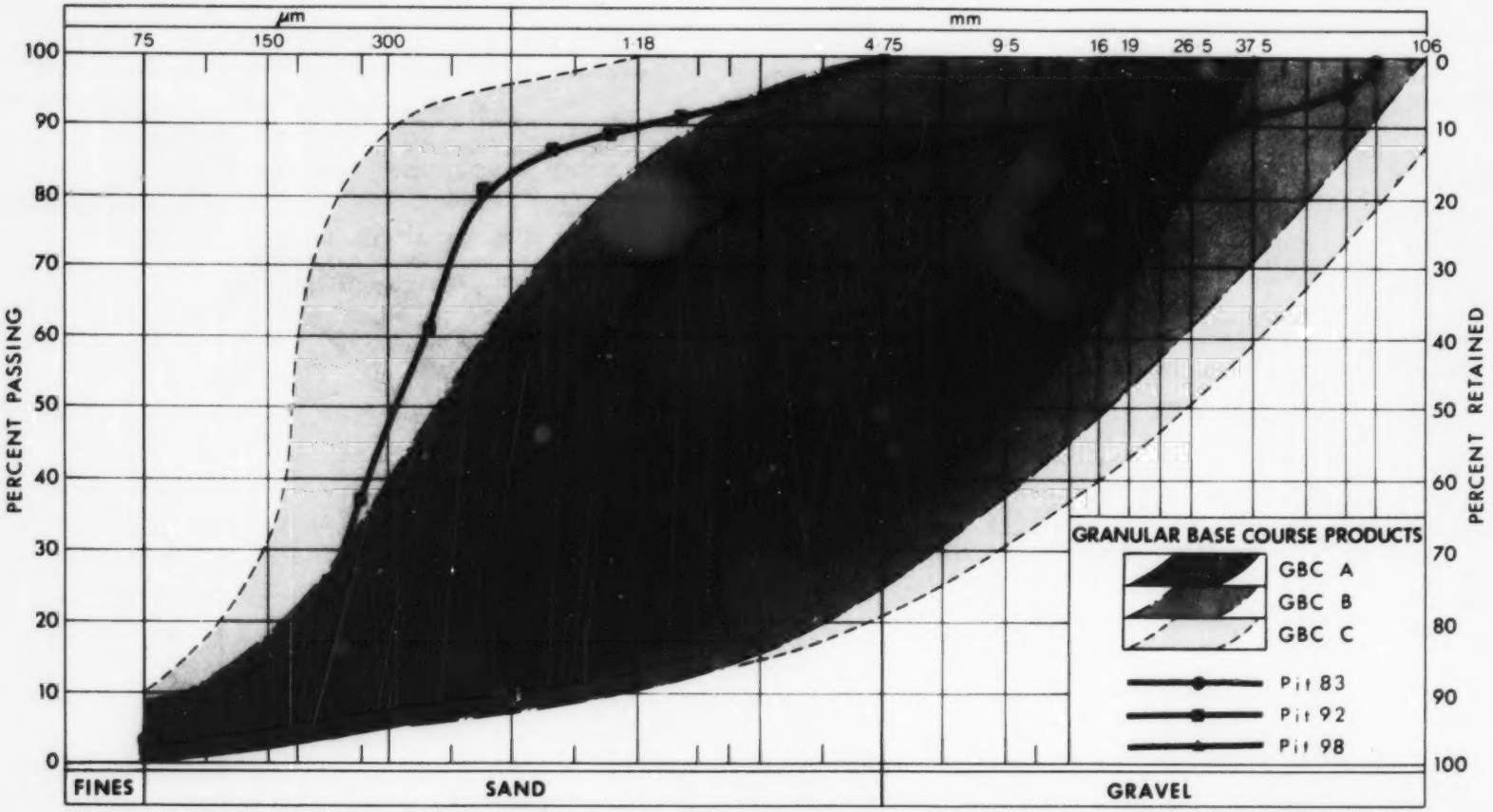


FIGURE 5a. AGGREGATE GRADING CURVES, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Form 1010, 1980).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

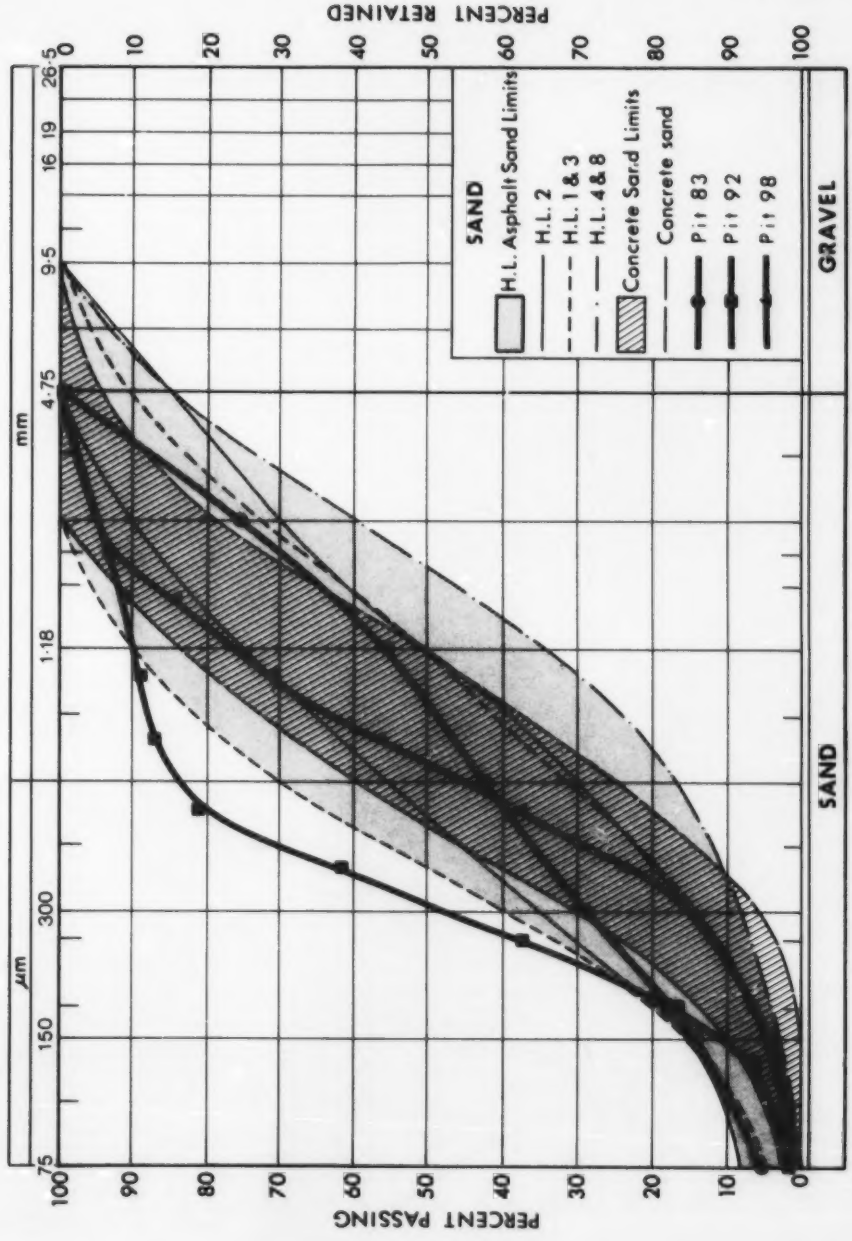


FIGURE 5b. AGGREGATE GRADING CURVES, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Forms 1002, 1979 and 1003, 1981).

NOTE: Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

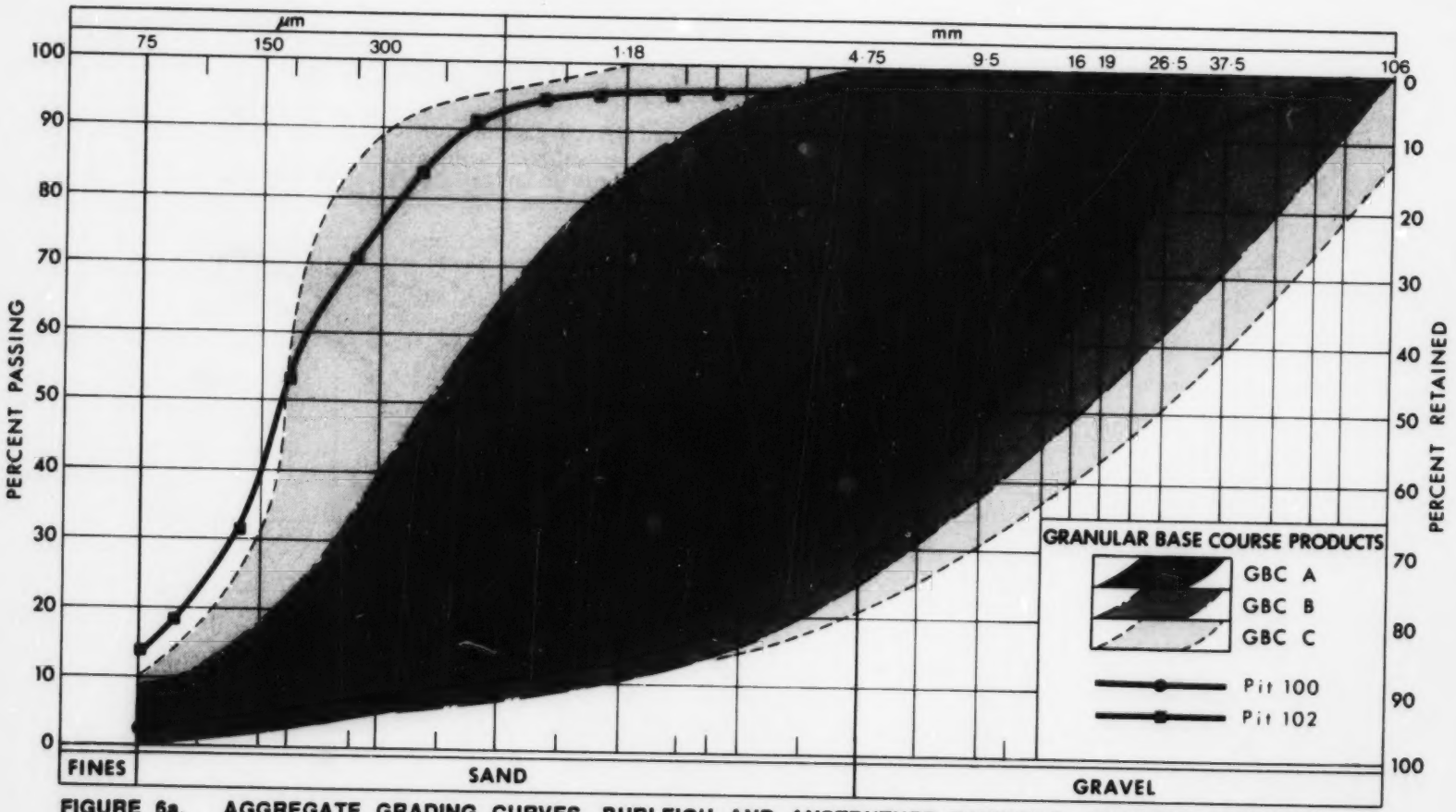


FIGURE 6a. AGGREGATE GRADING CURVES, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Form 1010, 1980).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

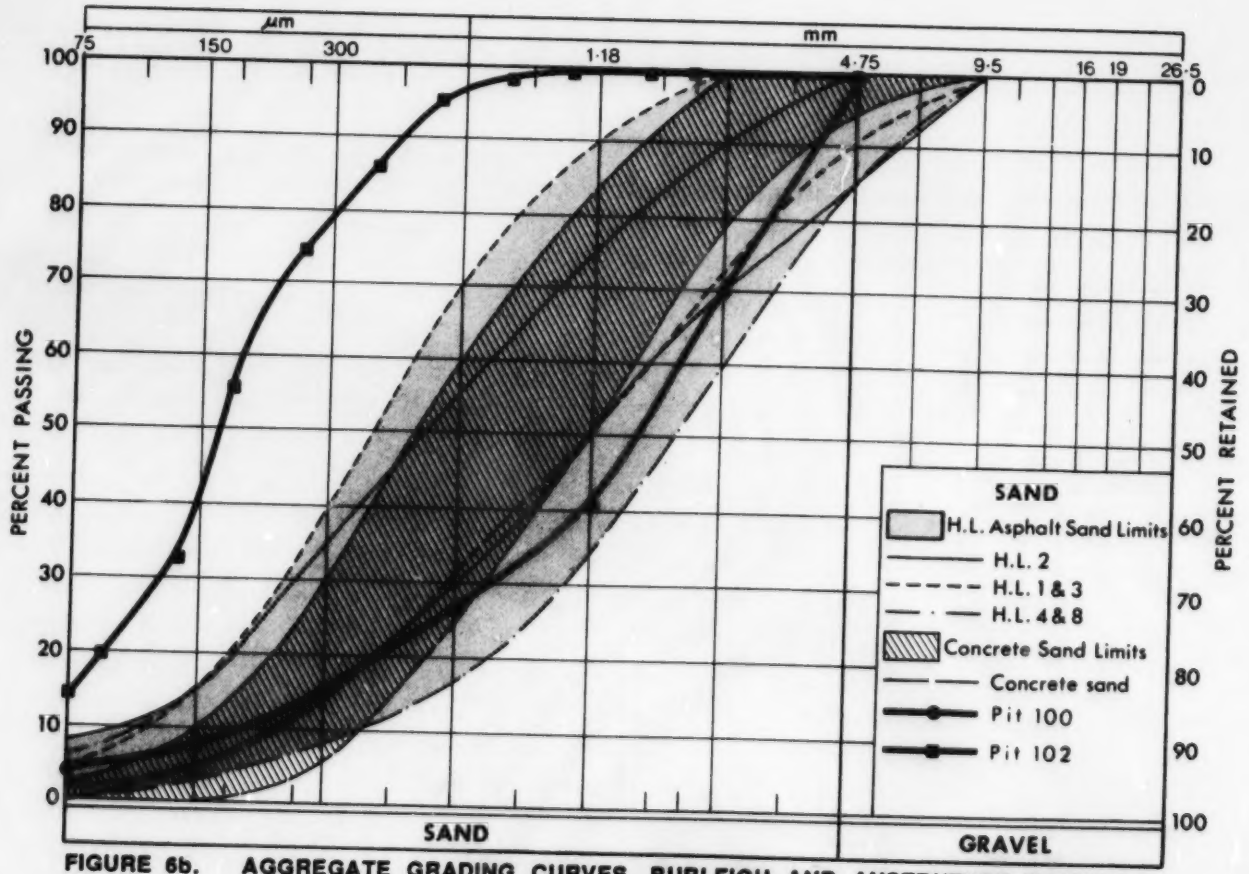


FIGURE 6b. AGGREGATE GRADING CURVES, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Forms 1002, 1979 and 1003, 1981).

NOTE: Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

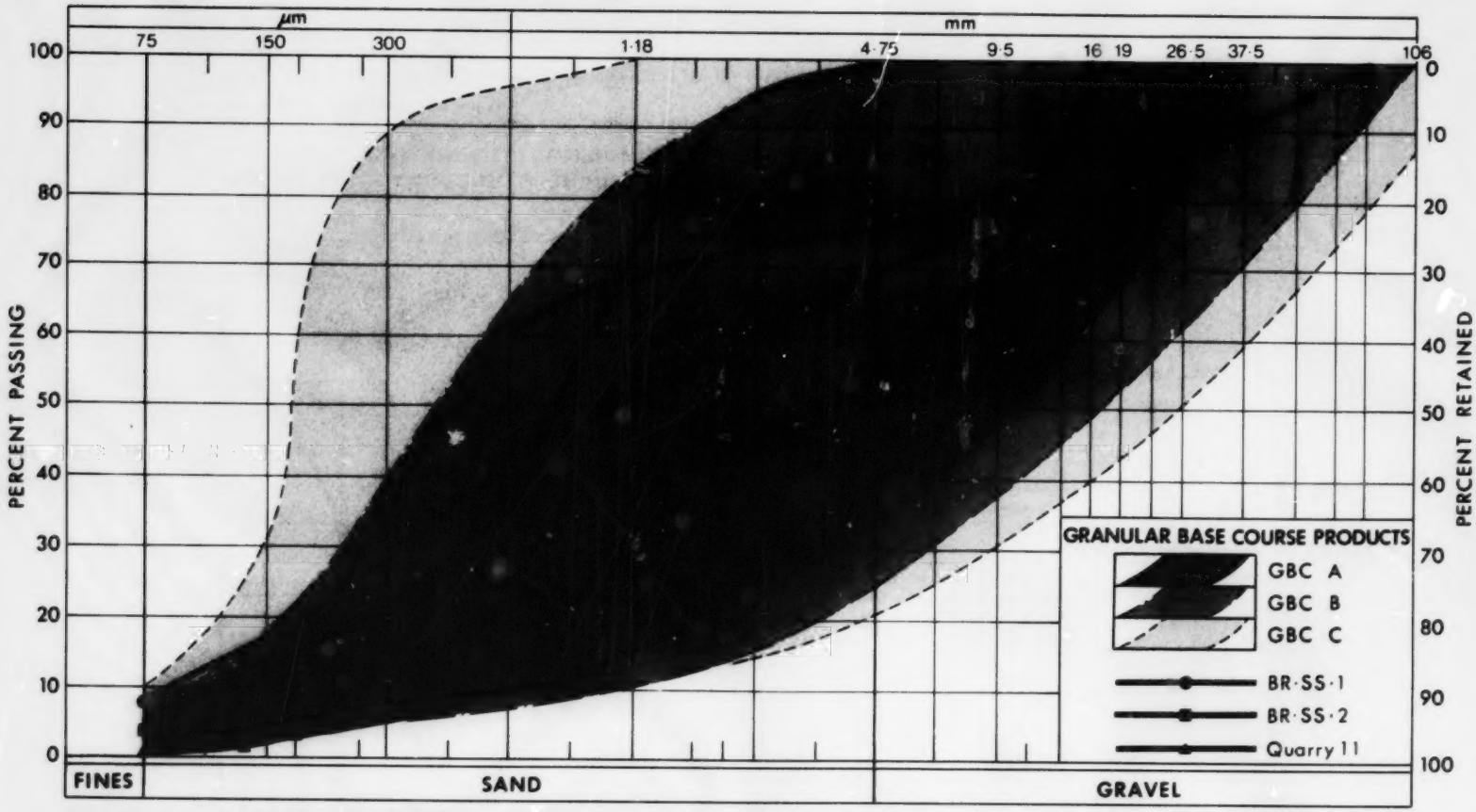


FIGURE 7a. AGGREGATE GRADING CURVES, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Form 1010, 1980).

NOTE:

Information portrayed by grading curves applies strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

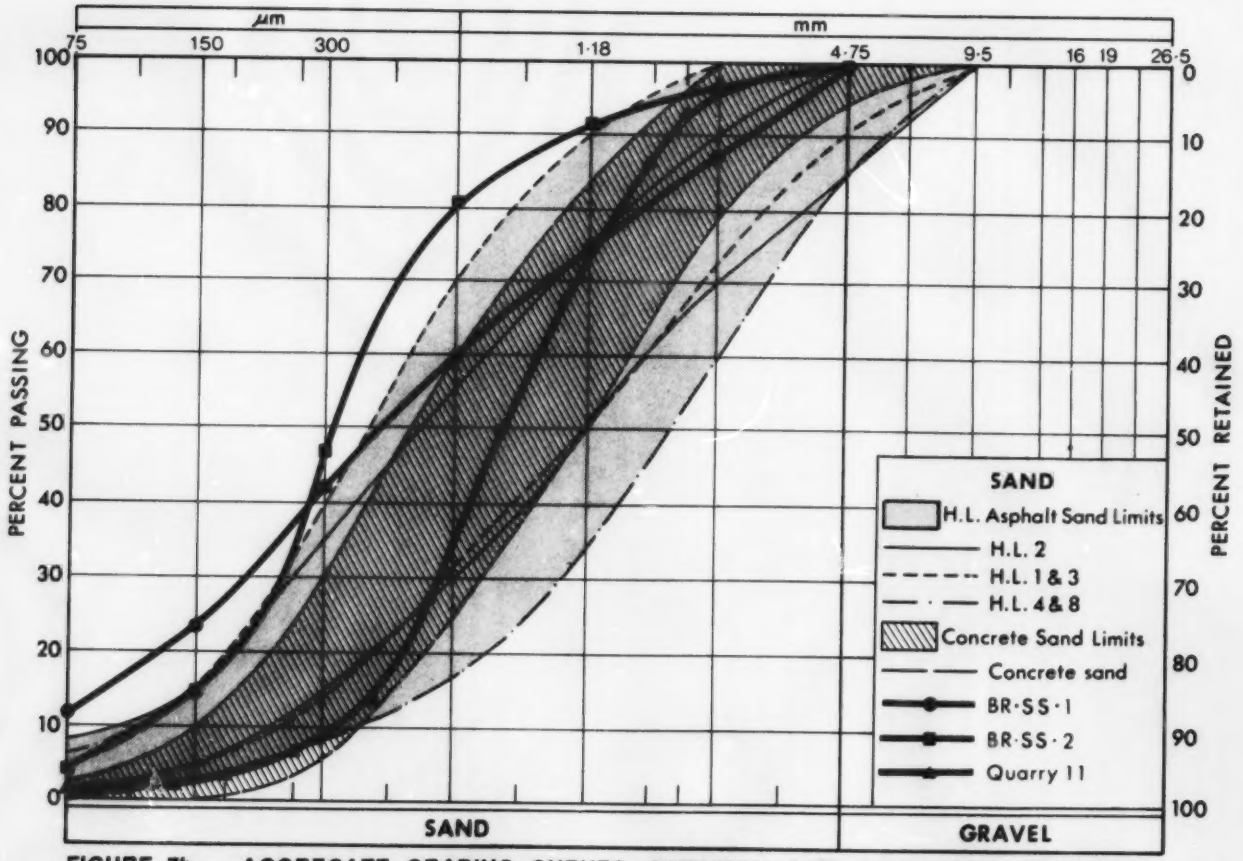


FIGURE 7b. AGGREGATE GRADING CURVES, BURLEIGH AND ANSTRUTHER TOWNSHIP, CHANDOS TOWNSHIP AND METHUEN GEOGRAPHIC TOWNSHIP.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Forms 1002, 1979 and 1003, 1981).

NOTE: Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

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Appendix A — Suggested Additional Reading

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Appendix B — Glossary

Abrasion resistance: Tests such as the Los Angeles abrasion test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

Absorption capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Aggregate: Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

Aggregate Abrasion Value: This test directly measures the resistance of aggregate to abrasion with silica sand and a steel disk. The higher the value, the lower the resistance to abrasion. For high quality asphalt surface course uses, values of less than 6 are desirable.

Alkali-aggregate reaction: A chemical reaction between the alkalis of portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

Beneficiation: Beneficiation of aggregates is a process or combination of processes which improves the quality (physical properties) of a mineral aggregate and is not part of the normal processing for a particular use, such as routine crushing, screening, washing or classification. Heavy media separation, jigging, or application of special crushers (e.g., "cage mill") are usually considered processes of beneficiation.

Blending: Required in cases of extreme coarseness, fineness, or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

Bulk Relative Density: An aggregate with low relative density is lighter in weight than one with a high relative density. Low relative density aggregates (less than about 2.5) are often non-durable for many aggregate uses.

Cambrian: The first period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago. The Cambrian precedes the Ordovician Period.

Clast: An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical weathering of larger rock mass. Synonyms include particle and fragment.

Crushable aggregate: Unprocessed gravel containing a minimum of 35% coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20% greater than the 26.5 mm sieve.

Deleterious lithology: A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

Devonian: A period of the Paleozoic Era thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

Dolostone: A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

Drift: A general term for all unconsolidated rock debris transported from one place and deposited in another, distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

Drumlin: A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were formed beneath an advancing ice sheet, and were shaped by its flow.

Eolian: Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

Fines: A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

Glacial lobe: A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced then melted back numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

Gneiss: A coarse-textured metamorphic rock with the minerals arranged in parallel streaks or bands. Gneiss is

relatively rich in feldspar. Other common minerals found in this rock include quartz, mica, amphibole and garnet.

Gradation: The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

Granite: A coarse-grained, light-coloured rock that ordinarily has an even texture and is composed of quartz, and feldspar with either mica, hornblende or both.

Granular base course: Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

Hot-laid (or asphaltic) aggregate: Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (HL 1, 3 and 4), or as binder course (HL 2 and 8) used to bind the surface course to the underlying granular base course.

Lithology: The description of rocks on the basis of such characteristics as colour, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

Los Angeles Abrasion and Impact Test: This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported, and placed. Values less than about 35% indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45% indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible to freezing and thawing will usually break down and give high losses in this test. Values greater than about 12 to 15% indicate potential problems for concrete and asphalt coarse aggregate.

Meltwater channel: A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

Ordovician: An early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

Paleozoic era: One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

Petrographic examination: Individual aggregate particles in a sample are divided into categories good, fair, poor, and deleterious, based on their rock type (petrography) and knowledge of past field performance. A petrographic number (PN) is calculated. The higher the PN, the lower the quality of the aggregate.

Pleistocene: An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

Polished Stone Value: This test measures the frictional properties of aggregates after 6 hours of abrasion and polishing with an emery abasive. The higher the PSV, the higher the frictional properties of the aggregate. Values less than 45 indicate marginal frictional properties, while values greater than 55 indicate excellent frictional properties.

Possible resource: Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

Precambrian: The earliest geological period extending from the consolidation of the earth's crust to the beginning of the Cambrian.

Shale: A fine-grained, sedimentary rock formed by the consolidation of clay, silt or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone and mudstone.

Silurian: An early period of the Palezoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

Soundness: The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

Till: Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

Wisconsinan: Pertaining to the last glacial period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

Appendix C — Geology of Sand and Gravel Deposits

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice-Contact Terraces (ICT): These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive because of the variability of the deposits both in terms of quality and grain size distribution.

Kames (K): Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuities. The deposits consist mainly of irregularly bedded and cross-bedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt- and clay-sized particles).

Eskers (E): Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers, consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

Undifferentiated Ice-Contact Stratified Drift (IC): This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits because of their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

Outwash (OW): Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

Subaqueous Fan (SF): Subaqueous fans are formed within or near the mouths of meltwater conduits when sediment laden meltwaters are discharged into a standing body of water. The geometry of the resulting deposit is fan or lobe shaped. Several of these lobes may be joined together to form a larger, continuous sedimentary body. Internally, subaqueous fans consist of stratified sands and gravels which may exhibit wide variations in grain size distribution. As these features were deposited under glacial lake waters, silt and clay which settled out of these lakes may be associated in varying amounts with these deposits. The variability of the sediments and presence of fines are the main extractive problems associated with these deposits.

Alluvium (AL): Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have gen-

erally low value because of the presence of excess silt- and clay-sized material. There are few large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

Glaciolacustrine Beach Deposits (LB): These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the source material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

Glaciolacustrine Deltas (LD): These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

Glaciolacustrine Plains (LP): The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

End Moraines (EM): These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

Windblown Deposits (WD): Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consist of fine to coarse sand and are usually well sorted. The probabiltiy of locating crushable aggregate in windblown deposits is very low.

Appendix D — Geology of Bedrock Deposits

The purpose of this appendix is to familiarize the reader with the general bedrock geology of southern Ontario (Figure D1), and the potential uses of the various bedrock formations where known. The reader is cautioned against using this information for more specific purposes. The stratigraphic chart (Figure D2) is intended only to illustrate the stratigraphic sequences in particular geographic areas and should not be used as a regional correlation table.

The following description is arranged in ascending stratigraphic order, on a group and formation basis. Precambrian rocks are not discussed. Additional stratigraphic information is included for some formations where necessary. The publications and maps of the Ontario Geological Survey and the Geological Survey of Canada should be referred to for more detailed information. The composition, thickness, and uses of the formations are discussed. If a formation may be suitable for use as aggregate and aggregate suitability test data is available, the data has been included in the form of ranges. The following short forms have been used in presenting this data: PSV = Polished Stone Value, AAV = Aggregate Abrasion Value, $MgSO_4$ = Magnesium Sulphate Soundness Test (loss in percent), LA = Los Angeles Abrasion and Impact Test (loss in percent), Absn = Absorption (percent), BRD = Bulk Relative Density, PN (Asphalt & Concrete) = Petrographic Number for Asphalt and Concrete use.

The ranges are intended as a guide only and care should be exercised in extrapolating the information to specific situations. Aggregate suitability test data has been provided by the Ontario Ministry of Transportation.

Covey Hill Formation (Cambrian)

STRATIGRAPHY: lower formation of the Potsdam Group. COMPOSITION: interbedded non-calcareous feldspathic conglomerate and sandstone. THICKNESS: 0 to 45 feet (0 to 14 m). USES: has been quarried for aggregate in South Burgess Township, Leeds County.

Nepean Formation (Cambro-Ordovician)

STRATIGRAPHY: upper formation of the Potsdam Group. COMPOSITION: thin-bedded to massive quartz sandstone with some conglomerate interbeds and rare shaly partings. THICKNESS: 0 to 100 feet (0 to 30 m). USES: suitable as dimension stone; quarried at Philipsville and Forfar for silica sand; alkali-silica reactive in Portland cement concrete. AGGREGATE SUITABILITY TESTING: PSV = 54-68, AAV = 4-15, $MgSO_4$ = 9-32, LA = 44-90, Absn = 1.6-2.6, BRD = 2.38-2.50, PN (Asphalt & Concrete) = 130-140.

March Formation (Lower Ordovician)

STRATIGRAPHY: lower formation of the Beekmantown Group. COMPOSITION: interbedded quartz sandstone, dolomitic quartz sandstone, sandy dolostone and dolostone. THICKNESS: 60 to 197 feet (18 to 60 m). USES: quarried extensively for aggregate in area of subcrop and outcrop; alkali-silica reactive in Portland cement concrete; lower part of formation is an excellent source of skid-resistant aggregate; suitable for use as facing stone and paving stone. AGGREGATE SUITABILITY TESTING: PSV = 55-60, AAV = 4-6, $MgSO_4$ = 1-17, LA = 15-38, Absn = 0.5-0.9, BRD = 2.61-2.65, PN (Asphalt & Concrete) = 110-150.

Oxford Formation (Lower Ordovician)

STRATIGRAPHY: upper formation of the Beekmantown Group. COMPOSITION: thin- to thick-bedded, microcrystalline to medium-crystalline, grey dolostone with thin shaly interbeds. THICKNESS: 200 to 335 feet (61 to 102 m). USES: quarried in the Brockville and Smith Falls areas and south of Ottawa for use as aggregate. AGGREGATE SUITABILITY TESTING: PSV = 47-48, AAV = 7-8, $MgSO_4$ = 1-4, LA = 18-23, Absn = 0.7-0.9, BRD = 2.74-2.78, PN (Asphalt & Concrete) = 105-120.

Rockcliffe Formation (Middle Ordovician)

STRATIGRAPHY: divided into lower member and upper (St. Martin) member. COMPOSITION: interbedded quartz sandstone and shale; interbedded shaly bioclastic limestone and shale predominating in upper member to the east. THICKNESS: 0 to 410 feet (0 to 125 m). USES: upper member has been quarried east of Ottawa for aggregate; lower member has been used as crushed stone; some high purity limestone beds in upper member may be suitable for use as fluxing stone and in lime production. AGGREGATE SUITABILITY TESTING: PSV = 58-63, AAV = 10-11, $MgSO_4$ = 12-40, LA = 25-28, Absn = 1.8-1.9, BRD = 2.55-2.62, PN (Asphalt & Concrete) = 122-440.

Shadow Lake Formation (Middle Ordovician)

STRATIGRAPHY: eastern Ontario - the basal unit of the Ottawa Group; central Ontario - overlain by the Simcoe Group. COMPOSITION: in eastern Ontario - silty and sandy dolostone with shale partings and minor interbeds of sandstone; in central Ontario - conglomer-

ates, sandstones, and shales. THICKNESS: eastern Ontario - 7 to 10 feet (2 to 3 m); central Ontario - 0 to 40 feet (0 to 12 m). USES: potential source of decorative stone; very limited value as aggregate source.

Gull River Formation (Middle Ordovician)

STRATIGRAPHY: part of the Simcoe Group (central Ontario) and Ottawa Group (eastern Ontario). In central and eastern Ontario the formation is subdivided into upper and lower members; west of Lake Simcoe it is presently subdivided into upper, middle and lower members. COMPOSITION: in central and eastern Ontario the lower member consists of alternating units of limestone, dolomitic limestone, and dolostone, the upper member consists of thin-bedded limestones with thin shale partings; west of Lake Simcoe the lower member is thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone, whereas the upper and middle members are dense microcrystalline limestones with argillaceous dolostone interbeds. THICKNESS: 23 to 204 feet (7 to 62 m). USES: quarried in the Lake Simcoe, Kingston, Ottawa, and Cornwall areas for crushed stone; rock from certain layers in eastern and central Ontario has proven to be alkali-reactive when used in Portland cement concrete (alkali-carbonate reaction). AGGREGATE SUITABILITY TESTING: PSV = 41-49, AAV = 8-12, $MgSO_4$ = 3-13, LA = 18-28, Absn = 0.3-0.9, BRD = 2.68-2.73, PN (Asphalt & Concrete) = 100-153.

Bobcaygeon Formation (Middle Ordovician)

STRATIGRAPHY: part of the Simcoe Group (central Ontario) and the Ottawa Group (eastern Ontario), subdivided into upper, middle and lower members; members in eastern and central Ontario are approximately equivalent. COMPOSITION: homogeneous, massive to thin-bedded fine-crystalline limestone with numerous shaly partings in the middle member. THICKNESS: 80 to 285 feet (24 to 87 m). USES: quarried at Brechin, Marysville, and in the Ottawa area for crushed stone; generally suitable for use as granular base course aggregate; rock from certain layers has been found to be alkali-reactive when used in Portland cement concrete (alkali-silica reaction). AGGREGATE SUITABILITY TESTING: PSV = 47-51, AAV = 14-23, $MgSO_4$ = 1-40, LA = 18-32, Absn = 0.3-2.4, BRD = 2.5-2.69, PN (Asphalt & Concrete) = 100-320.

Verulam Formation (Middle Ordovician)

STRATIGRAPHY: part of Simcoe and Ottawa Groups. COMPOSITION: fossiliferous, pure to argillaceous limestone interbedded with calcareous shale. THICKNESS: 105 to 230 feet (32 to 70 m). USES: quarried at Picton and Bath for use in cement manufacture; quarried for aggregate in Mara Township, Simcoe County and in the Belleville-Kingston area; may be unsuitable for use as aggregate in some areas because of its high shale content. AGGREGATE SUITABILITY TESTING: PSV = 43-44, AAV = 9-13, $MgSO_4$ = 4-45, LA = 22-29, Absn = 0.4-2.1, BRD = 2.59-2.70, PN (Asphalt & Concrete) = 120-255.

Lindsay Formation (Middle and Upper Ordovician)

STRATIGRAPHY: part of Simcoe and Ottawa Groups; in eastern Ontario is divisible into an unnamed lower member and the Eastview Member; in central Ontario is divisible into the Collingwood Member (equivalent to portions of the Eastview Member) and a lower member. COMPOSITION: in eastern Ontario the lower member is interbedded, very fine- to coarse-crystalline limestone with undulating shale partings and interbeds of dark grey calcareous shale, whereas the Eastview Member is an interbedded dark grey to dark brown calcareous shale and very fine- to fine-crystalline, petroliferous limestone; in central Ontario Collingwood Member is a black, calcareous shale whereas the lower member is a very fine- to coarse-crystalline, thin-bedded limestone with very thin, undulating shale partings. THICKNESS: 82 to 200 feet (25 to 61 m). USES: in eastern Ontario the lower member is used extensively for aggregate production; in central Ontario it is quarried at Picton, Ogden Point and Bowmanville for cement; may be suitable or unsuitable for use as concrete and asphalt aggregate. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 2-47, LA = 20-28, Absn = 0.4-1.3, BRD = 2.64-2.70, PN (Asphalt & Concrete) = 110-215.

Blue Mountain and Billings Formations (Upper Ordovician)

STRATIGRAPHY: central Ontario - Blue Mountain Formation includes the upper and middle members of the former Whitby Formation; eastern Ontario - Billings Formation is equivalent to part of the Blue Mountain Formation. COMPOSITION: the Blue Mountain Formation is blue-grey, noncalcareous shales; Billings Formation is dark grey to black, noncalcareous to slightly calcareous, pyritiferous shale with dark grey limestone laminae and grey siltstone interbeds. THICKNESS: Blue Mountain Formation - 140 to 200 feet (43 to 61 m); Billings Formation - 0 to 205 feet (0 to 62 m). USES: Billings Formation may be a suitable source for structural clay products and expanded aggregate; Blue Mountain Formation may be suitable for structural clay products.

Georgian Bay and Carlsbad Formations (Upper Ordovician)

COMPOSITION: in central Ontario the Georgian Bay Formation is composed of interbedded limestone and shale; in eastern Ontario the Carlsbad Formation is composed of interbedded shale, siltstone and bioclastic limestone; THICKNESS: Georgian Bay Formation is 300 to 560 feet (91 to 170 m); Carlsbad Formation - 0 to 610 feet (0 to 186 m). USES: Georgian Bay Formation is

used by several producers in Metropolitan Toronto area to produce brick and structural tile, as well as for making Portland cement; at Streetsville, expanded shale was used in the past to produce lightweight aggregate; Carlsbad Formation is used as a source material for brick and tile manufacturing, has potential as a lightweight expanded aggregate.

Queenston Formation (Upper Ordovician)

COMPOSITION: red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. THICKNESS: 400 to 500 feet (122 to 152 m). USES: there are several large quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa; all extract shale for brick manufacturing; the Queenston Formation is the most important source material for brick manufacture in Ontario.

Whirlpool Formation (Lower Silurian)

STRATIGRAPHY: lower formation in the Cataract Group in the Niagara Penninsula and the Niagara Escarpment as far north as Duntroon. COMPOSITION: massive, medium- to coarse-grained, argillaceous white to light grey quartz sandstone with thin grey shale partings. THICKNESS: 0 to 25 feet (0 - 8 m). USES: building stone, flagstone.

Manitoulin Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs north of Stoney Creek. COMPOSITION: thin-bedded, blue-grey to buff-brown dolomitic limestones and dolostones. THICKNESS: 0 to 75 feet (0 to 23 m). USES: extracted for crushed stone in St. Vincent Township, Grey County, and for decorative stone on Manitoulin Island. AGGREGATE SUITABILITY TESTING: no data.

Cabot Head Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs throughout southern Ontario, south and north of the Niagara Escarpment. COMPOSITION: green, grey and red shales. THICKNESS: 50 to 60 feet (15 to 18 m); USES: potential source of coated lightweight aggregate and raw material for use in manufacture of brick and tile; lack of suitable exposures has limited its use.

Grimsby Formation

STRATIGRAPHY: upper formation of the Cataract Group, is identified on the Niagara Peninsula as far north as Clappison's Corners. COMPOSITION: interbedded sandstone and shale, mostly red. THICKNESS: 0 to 50 feet (0 to 15 m). USES: no present uses.

Thorold Formation (Middle Silurian)

STRATIGRAPHY: lower formation in the Clinton Group on the Niagara Peninsula. COMPOSITION: thick-bedded quartz sandstone. THICKNESS: 7 to 10 feet (2 - 3 m). USES: no present uses.

Neagha Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on the Niagara Peninsula. COMPOSITION; dark grey to green shale with minor interbedded limestone. THICKNESS: 0 to 5 feet (0 to 2 m). USES: no present uses.

Dyer Bay Formation (Middle Silurian)

STRATIGRAPHY: lower formation in the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: highly fossiliferous, impure dolostone. THICKNESS: 0 to 20 feet (0 to 6 m). USES: no present uses.

Wingfield Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: olive green to grey shale with dolostone interbeds. THICKNESS: 0 to 36 feet (0 to 11 m). USES: no present uses.

St. Edmund Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula, upper portion previously termed the Mindemoya Formation. COMPOSITION: pale grey to buff brown, micro- to medium-crystalline, thin- to medium-bedded dolostone. THICKNESS: 0 to 85 feet (0 to 26 m). USES: quarried for fill and crushed stone on Manitoulin Island. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 1-2, LA = 19-21, Absn = 0.6-0.7, BRD = 2.78-2.79, PN (Asphalt & Concrete) = 105.

Fossil Hill and Reynales Formations (Middle Silurian)

STRATIGRAPHY: part of Clinton Group; Fossil Hill Formation occurs in the northern part of the Niagara Escarpment and is approximately equivalent in part, to the Reynales Formation which occurs on the Niagara Peninsula and the Escarpment, as far north as the Forks of the Credit. COMPOSITION: Fossil Hill Formation is fine- to coarse-crystalline dolostone with high silica content; Reynales Formation is thin- to thick-bedded shaly dolostone and dolomitic limestone. THICKNESS: Fossil Hill Formation - 20 to 85 feet (6 to 26 m); Reynales Formation - 0 to 10 feet (0 to 3 m). USES: both formations quarried for aggregate with overlying Amabel and Lockport Formations. AGGREGATE SUITABILITY TESTING: (Fossil Hill Formation on Manitoulin Island) $MgSO_4$ = 41, LA = 29, Absn = 4.1, BRD = 2.45, PN (Asphalt & Concrete) = 370.

Irondequoit Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group on the Niagara Peninsula south of Waterdown. COMPOSITION: massive, coarse-crystalline crinoidal limestone. THICKNESS: 0 to 7 feet (0 to 2 m). USES: not significantly utilized.

Rochester Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group along the Niagara Peninsula. COMPOSITION: black to dark grey calcareous shale with numerous limestone lenses. THICKNESS: 15 to 60 feet (5 to 18 m). USES: not significantly utilized. AGGREGATE SUITABILITY TESTING: PSV = 69, AAV = 17, $MgSO_4$ = 95, LA = 19, Asbn = 2.2, BRD = 2.67, PN (Asphalt & Concrete) = 400.

Decew Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group south of Waterdown along the Niagara Peninsula. COMPOSITION: sandy to shaly dolomitic limestone and dolostone. THICKNESS: 0 to 15 feet (0 to 5 m). USES: too shaly for high quality uses, but is quarried along with Lockport Formation in places. AGGREGATE SUITABILITY TESTING: PSV = 67, AAV = 15, $MgSO_4$ = 55, LA = 21, Absn = 2.2, BRD = 2.66, PN (Asphalt & Concrete) = 255.

Lockport and Amabel Formations (Middle Silurian)

STRATIGRAPHY: Lockport Formation occurs from Waterdown to Niagara Falls, subdivided into 3 formal members: Gasport, Goat Island and Eramosa Members and an informal member (the "Vinemount shale beds"); the stratigraphically equivalent Amabel Formation, found from Waterdown to Cockburn Island, is subdivided into Lions Head, Wiarton/Colpoy Bay, and Eramosa members. COMPOSITION: Lockport Formation is thin- to massive-bedded, fine- to medium-crystalline dolostone; Amabel Formation is thin bedded to massive, medium-crystalline dolostone with reef facies near Georgetown and on the Bruce Peninsula. THICKNESS: (Lockport/ Amabel) 10 to 130 feet (3 to 40 m). USES: both formations have been used to produce lime, crushed stone, concrete aggregate, and building stone throughout their area of occurrence, and are a resource of provincial significance. AGGREGATE SUITABILITY TESTING: PSV = 36-49, AAV = 10-17, $MgSO_4$ = 2-6, LA = 25-32, Absn = 0.4-1.54, BRD = 2.61-2.81, PN (Asphalt & Concrete) = 100-105.

Guelph Formation (Middle Silurian)

STRATIGRAPHY: exposed on the Niagara Escarpment from the Niagara River to the tip of the Bruce Peninsula, mostly present in the subsurface of southwestern Ontario. COMPOSITION: micro-crystalline to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies of high chemical purity. THICKNESS: 100 to 170 feet (30 to 52 m). USES: some areas appear soft and unsuitable for use in the production of load-bearing aggregate; this unit requires additional testing to fully establish its aggregate suitability; main use is for dolomitic lime for cement manufacture; quarried near Hamilton and Guelph.

Salina Formation (Upper Silurian)

STRATIGRAPHY: present in the subsurface of southwestern Ontario; rarely exposed at the surface. COMPOSITION: grey and maroon shale, brown dolostone and, in places, salt, anhydrite and gypsum; consists predominantly of evaporitic rich material with up to eight units identifiable. THICKNESS: 370 to 600 feet (113 to 183 m). USES: gypsum mines at Hagersville, Caledonia, and Drumbo; salt is mined at Goderich and Windsor, and is produced from brine wells at Amherstburg, Windsor and Sarnia.

Bertie and Bass Islands Formations (Upper Silurian)

STRATIGRAPHY: Bertie Formation found in southern Niagara Peninsula; Bass Islands Formation, the Michigan Basin equivalent of the Bertie Formation, does not significantly outcrop in Ontario but is present in the subsurface in southwestern Ontario; Bertie Formation represented by Oatka, Falkirk, Scajaquanda, Williamsville, and Akron Members. COMPOSITION: medium- to massive-bedded, micro-crystalline, brown dolostone with shaly partings. THICKNESS: 45 to 160 feet (14 to 49 m). USES: quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville and Dunnville; shaly intervals are unsuitable for use as high specification aggregate because of low freeze-thaw durability; has also been extracted for lime. AGGREGATE SUITABILITY TESTING: PSV = 46-49, AAV = 8-11, $MgSO_4$ = 4-19, LA = 14-23, Absn = 0.8-2.8, BRD = 2.61-2.78, PN (Asphalt & Concrete) = 102-120.

Oriskany Formation (Lower Devonian)

STRATIGRAPHY: basal Devonian clastic unit, found in Niagara Peninsula. COMPOSITION: thick- to massive-bedded, coarse-grained, grey-yellow sandstone. THICKNESS: 0 to 15 feet (0 to 5 m). USES: has been quarried for silica sand, building stone, and armour stone; may be acceptable for use as rip rap, and well cemented varieties may be acceptable for some asphaltic products. AGGREGATE SUITABILITY TESTING: (of a well cemented variety of the formation) PSV = 64, AAV = 6, $MgSO_4$ = 2, LA = 29, Absn = 1.2-1.3, BRD = 2.55, PN (Asphalt & Concrete) = 107.

Bois Blanc Formation (Lower Devonian)

STRATIGRAPHY: Springvale Sandstone Member forms the lower portion of formation. COMPOSI-

TION: a cherty limestone with shale partings and minor interbedded dolostones; Springvale Sandstone Member is a medium- to coarse-grained, green glauconitic sandstone with interbeds of limestone, dolostone and brown chert. THICKNESS: 10 to 130 feet (3 to 40 m). USES: quarried at Hagersville, Cayuga, and Port Colborne for crushed stone; material generally unsuitable for concrete aggregate because of high chert content. AGGREGATE SUITABILITY TESTING: PSV = 48-53, AAV = 3-7, $MgSO_4$ = 3-18, LA = 15-22, Absn = 1.3-2.8, BRD = 2.50-2.70, PN (Asphalt & Concrete) = 102-290.

Onondaga Formation (Middle Devonian)

STRATIGRAPHY: correlated to part of the Detroit River Group; occurs on the Niagara Peninsula from Simcoe to Niagara Falls; contains the Edgecliff, Clarence, and Moorehouse Members. COMPOSITION: medium-bedded, fine- to coarse-grained, dark grey-brown or purplish-brown, variably cherty limestone. THICKNESS: 60 to 82 feet (18 to 25 m) USES: quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne; high chert content makes much of the material unsuitable for use as concrete aggregate and asphaltic concrete; has been used as a raw material in cement manufacture. AGGREGATE SUITABILITY TESTING: (Clarence and Edgecliff Members) $MgSO_4$ = 1-6, LA = 16.8-22.4, Absn = 0.5-1.1, PN (Asphalt & Concrete) = 190-276.

Amherstburg Formation (Middle Devonian)

STRATIGRAPHY: part of Detroit River Group; correlated to Onondaga Formation in Niagara Penninsula; contains Sylvania Sandstone Member and Formosa Reef Limestone. COMPOSITION: bituminous, bioclastic, stromatoporoid-rich limestone and dolostone with grey chert nodules; Formosa Reef Limestone is high purity (calcium rich) limestone; Sylvania Sandstone Member is quartz sandstone. THICKNESS: 0 to 165 feet (0 to 50 m); Formosa Reef Limestone up to 85 feet (26 m). USES: cement manufacture, agricultural lime, aggregate. AGGREGATE SUITABILITY TESTING: PSV = 57, AAV = 19, $MgSO_4$ = 9-35, LA = 26-52, Absn = 1.1-6.4, BRD = 2.35-2.62, PN (Asphalt & Concrete) = 105-300.

Lucas Formation (Middle Devonian)

STRATIGRAPHY: part of the Detroit River Group in southwestern Ontario; includes the Anderdon Member which, in the Woodstock Beachville area, may constitute the bulk of the formation. COMPOSITION: light brown or grey-brown dolostone with bituminous laminations and minor chert; Anderdon Member consists of very high purity (calcium-rich) limestone. THICKNESS: 130 to 246 feet (40 to 75 m). USES: most important source of high-purity limestone in Ontario; used as calcium lime for metallurgical flux and for the manufacture of chemicals; rock of lower purity is used for cement manufacture, agricultural lime and aggregate; Anderdon Member is quarried at Amherstburg for crushed stone. AGGREGATE SUITABILITY TESTING: PSV = 46-47, AAV = 15-16, $MgSO_4$ = 2-60, LA = 22-47, Absn = 1.1-6.5, BRD = 2.35-2.40, PN (Asphalt & Concrete) = 110-160.

Dundee Formation (Middle Devonian)

STRATIGRAPHY: few natural outcrops, largely in the subsurface of southwestern Ontario. COMPOSITION: fine- to medium-crystalline, brownish-grey, medium- to thick-bedded, dolomitic limestone with shaly partings sandy layers, and chert in some areas. THICKNESS: 50 to 100 feet (15 to 30 m). USES: quarried near Port Dover and on Pelee Island for crushed stone; used at St. Marys as a raw material for Portland cement. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 1-28, LA = 22-46, Absn = 0.6-6.8, PN (Asphalt & Concrete) = 125-320.

Marcellus Formation (Middle Devonian)

STRATIGRAPHY: subsurface unit, mostly found below Lake Erie and extending into the eastern U.S.A., pinches out in the Port Stanley area. COMPOSITION: black, bituminous shales. THICKNESS: 0 to 15 feet (0 to 5 m). USES: no present uses.

Bell Formation (Middle Devonian)

STRATIGRAPHY: lowest formation of the Hamilton Group, no outcrop in Ontario. COMPOSITION: soft blue and grey calcareous shale. THICKNESS: 0 to 30 feet (0 to 9 m). USES: no present uses.

Rockport Quarry Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group; no outcrop in Ontario. COMPOSITION: grey-brown, very fine-grained limestone with occasional shale layers. THICKNESS: 0 to 20 feet (0 to 6 m). USES: no present uses.

Arkona Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: blue-grey, plastic, clay shale with occasional thin and laterally discontinuous limestone lenses. THICKNESS: 15 to 120 feet (5 to 37 m). USES: has been extracted at Thedford and near Arkona for the production of drainage tile.

Hungry Hollow Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: grey crinoidal limestone and soft, fossiliferous calcareous shale. THICKNESS: 0 to 6 feet (0 to 2 m). USES: suitable for some crushed stone and fill with selective quarrying. AGGREGATE SUITABILITY TESTING: No data.

Widder Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: mainly soft, grey, fossiliferous calcareous shale interbedded with blue-grey, fine-grained fossiliferous limestone. THICKNESS: 0 to 45 feet (0 to 14 m). USES: no present uses.

Ipperwash Formation (Middle Devonian)

STRATIGRAPHY: upper formation of the Hamilton Group; very limited distribution. COMPOSITION: medium- to coarse-grained, grey-brown, bioclastic limestone. THICKNESS: 5 to 45 feet (2-14 m). USES: no present uses.

Kettle Point Formation (Upper Devonian)

STRATIGRAPHY: occurs in a band between Sarnia and Erieau; small part overlain by Port Lambton Group rocks in extreme northwest. COMPOSITION: black, highly fissile, organic-rich shale with minor interbeds of grey-green silty shale. THICKNESS: 0 to 200 feet (0 to 61 m). USES: possible source of fill; possible source of material for use as sintered lightweight aggregate.

Bedford Formation (Upper Devonian)

STRATIGRAPHY: lower formation of the Port Lambton Group. COMPOSITION: soft, grey shale. THICKNESS: 0 to 108 feet (0 to 33 m). USES: no present uses.

Berea Formation (Upper Devonian)

STRATIGRAPHY: middle formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: grey, fine- to medium-grained sandstone, often dolomitic and interbedded with grey shale and siltstone. THICKNESS: 0 to 197 feet (0 to 60 m). USES: no present uses.

Sunbury Formation (Upper Devonian)

STRATIGRAPHY: upper formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: black shale. THICKNESS: 0 to 66 feet (0 to 20 m). USES: no present uses..

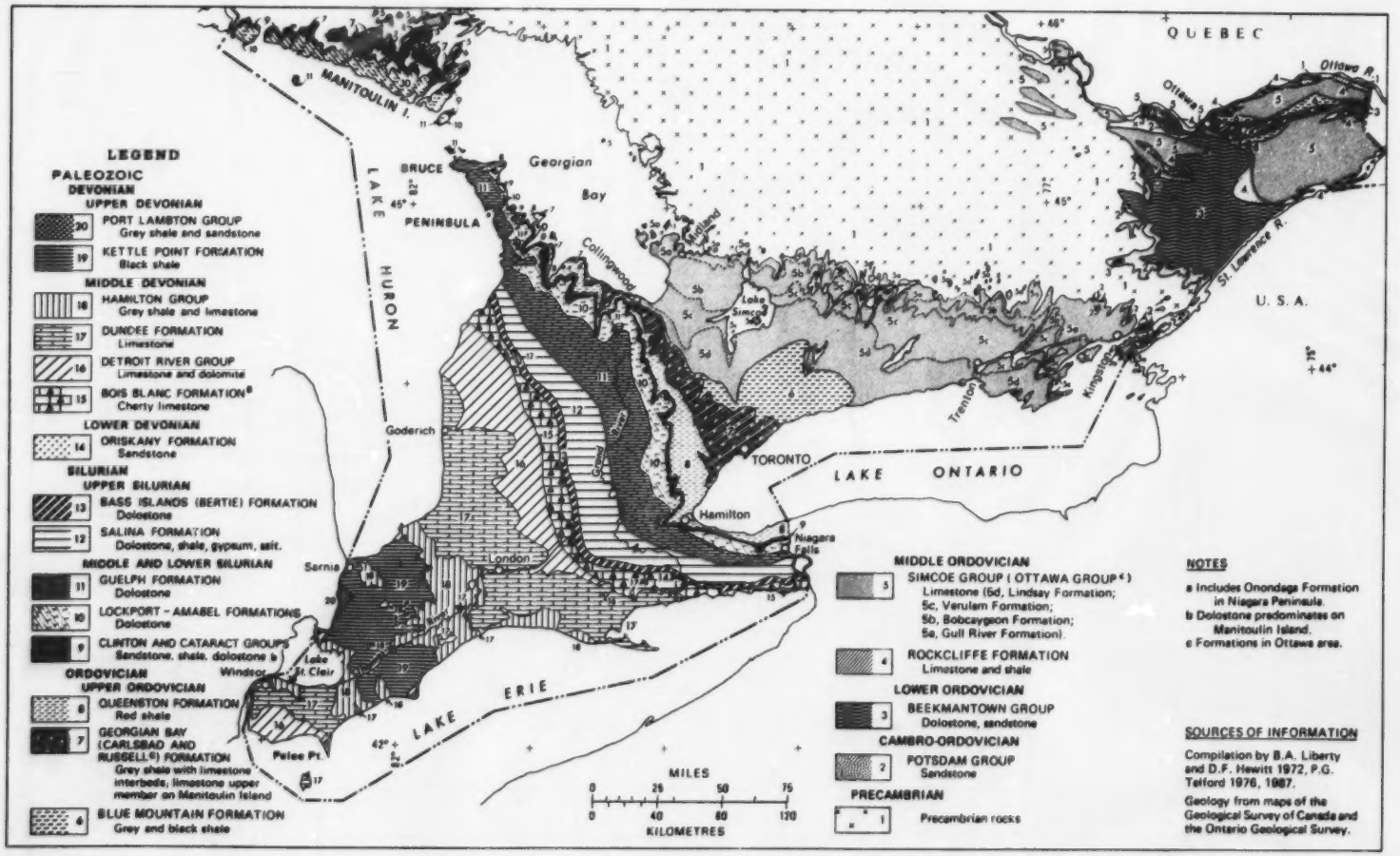

Figure D1. Bedrock Geology of Southern Ontario.

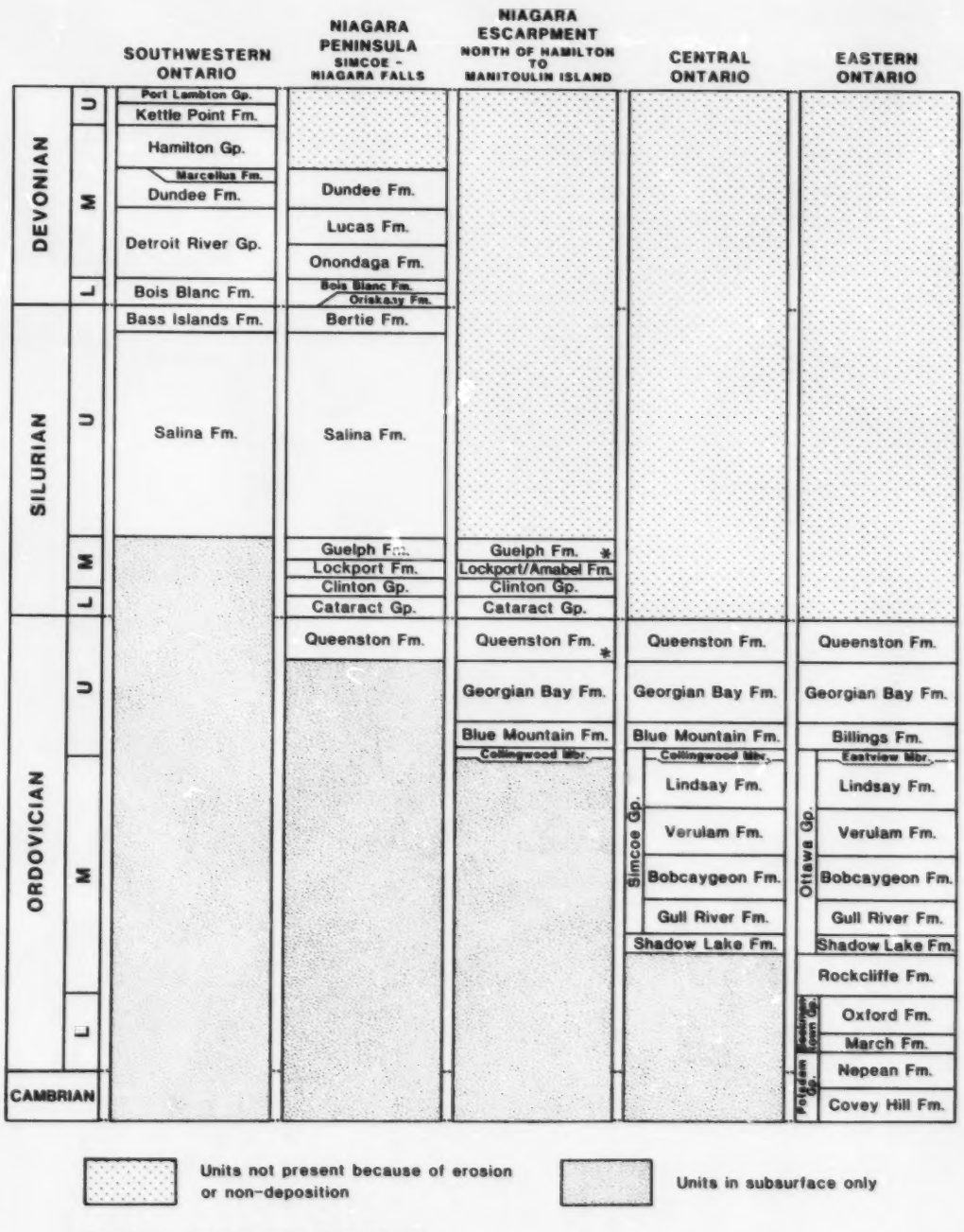

Figure D2. Exposed Paleozoic Stratigraphic Sequences in Southern Ontario
(adapted from: Bezys, R. K., and Johnson, M.D. 1988. The geology of the Paleozoic formations utilized by the limestone industry of Ontario; The Canadian Mining and Metallurgical Bulletin v.81, no.912, p.49–58).

Appendix E — Aggregate Quality Test Specifications

Four types of aggregate quality tests are often performed by the Ontario Ministry of Transportation on sampled material. A description of Table E1 and the specification limits for each test are given in this appendix. Although a specific sample meets or does not meet the specification limits for a certain product, it may or may not be acceptable for that use based on field performance. Additional quality tests other than the four major tests listed in this appendix can be used to determine the suitability of an aggregate. The tests are performed by the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation.

Absorption capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Los Angeles abrasion and impact test: This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported, and placed. Values less than about 35% indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45% indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible to freezing and thawing will usually break down and give high losses in this test. Values greater than about 12 to 15% indicate potential problems for concrete and asphalt coarse aggregate.

Petrographic examination: Individual aggregate particles in a sample are divided into categories good, fair, poor, and deleterious, based on their rock type (petrography) and knowledge of past field performance. A petrographic number (PN) is calculated. The higher the PN, the lower the quality of the aggregate.

TABLE E1. SELECTED QUALITY REQUIREMENTS FOR MAJOR AGGREGATE PRODUCTS.

	TYPE OF TEST				
	COARSE AGGREGATE				FINE AGGREGATE
TYPE OF MATERIAL	Petrographic Number Maximum	Magnesium Sulphate Soundness – Max. % Loss	Absorption Maximum %	Los Angeles Abrasion Maximum % Loss	Magnesium Sulphate Soundness Maximum % Loss
Granular Base A	200	–	–	60	–
16 mm Crushed Type 'A'	160	–	–	35	–
16 mm Crushed Type 'B'	200	–	–	60	–
Granular Subbase B	250	–	–	–	–
Granular Subbase C	250	–	–	–	–
Granular Subbase D	–	–	–	–	–
Hot Mix – HL 1	100	5	1.0	15	16
Hot Mix – HL 2	–	–	–	–	20
Hot Mix – HL 3	135	12	1.75	35	16
Hot Mix – HL 4	160	12	2.0	35	20
Hot Mix – HL 8	160	15	2.0	35	20
Structural Concrete and Concrete Base	140	12	2.0	35	16
Pavement Concrete and Exposed Structure Deck	125	12	2.0	35	16

(Ministry of Transportation Forms 1002, 1003 and 1010)

CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

MAPS
NOT
FILMED

CARTES
OMISES